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TECHNICAL MEMORANDUM

ANALYTIC PERFORMANCE EVALUATION RESULTS OF THE MID-FREQUENCY ACTIVE CLASSIFICATION PROCESSOR CW AND LFM NORMALIZERS

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PERFORMANCE OF THE MID-FREQUENCY ACTIVE CLASSIFICATION PROCESSOR (MFACP) PHASE 1 CONTINUOUS WAVE (CW) AND LINEAR FREQUENCY MODULATED (LFM) NORMALIZERS BASED ON AN ANALYTIC EVALUATION METHODOLOGY IS PRESENTED. THE PERFORMANCE RESULTS ARE QUANTIFIED IN THE FORM OF RECEIVER OPERATING CHARACTERISTIC (ROC) CURVES AT THE NORMALIZER OUTPUT. THE ROC CURVES DETERMINE THE SINGLE BIN PROBABILITY OF DETECTION (P(D)) AS A FUNCTION OF SIGNAL-TOP-NOISE RATIO(SNR) FOR SPECIFIED DESIGN PROBABILITY OF FALSE ALARM (P(F)) AT THE NORMALIZER OUTPUT. THE ROC CURVES SO GENERATED ARE FOR NORMALIZER PERFORMANCE WHEN SUBJECTED TO BOTH STATIONARY NOISE BACKGROUNDS AND NONSTATIONARY NOISE BACKGROUND VARIATIONS. THE NONSTATIONARY BACKGROUND CONSIDERED HAS A GENERALIZED SINUSOIDAL VARIATION OF THE RAYLEIGH PARAMETER OF THE ENVELOPE DETECTED, MATCHED FILTER OUTPUT WHERE BOTH THE AMPLITUDE AND PERIOD OF THE SINUSOID ARE ADJUSTABLE. IT IS SHOWN THAT WORSE CASE PERFORMANCE AS REFLECTED IN THE ROC CURVES OCCURS AT THE LOCAL MINIMUM AND MAXIMUM INTENSITIES OF THE SINUSOIDAL NONSTATIONARY. THE ROC CURVES AT ALL OTHER POINTS OF THE SINUSOID OSCILLATE BETWEEN THE MINIMUM AND MAXIMUM POINT ROC CURVES. THE CONSTANT FALSE ALARM RATE (CFAR) OUTPUT CAPABILITY F THE NORMALIZERS IS ALSO EVALUATED FOR FIXED DETECTION THRESHOLDS AS THE NORMALIZERS OPERATE ON THE STATIONARY AND NONSTATIONARY BACKGROUND.

14. SUBJECT TERMS
NORMALIZER, ROC, MFACP I CW/FM, STATIONARY/NONSTATIONARY NOISE, RAYLEIGH, PROBABILITY OF DETECTION, PROBABILITY OF FALSE ALARM, CONSTANT FALSE ALARM RATE (CFAR)

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ABSTRACT

Performance of the Mid-Frequency Active Classification Processor (MFACP) phase 1 Continuous Wave (CW) and Linear Frequency Modulated (LFM) normalizers based on an analytic evaluation methodology is presented. The performance results are quantified in the form of Receiver Operating Characteristic (ROC) curves at the normalizer output. The ROC curves determine the single bin probability of detection (P(D)) as a function of signal-to-noise ratio (SNR) for specified design probability of false alarm (P(F)) at the normalizer output. The ROC curves so generated are for normalizer performance when subjected to both stationary noise backgrounds and nonstationary noise background variations. The nonstationary background considered has a generalized sinusoidal variation of the Rayleigh parameter of the envelope detected, matched filter output where both the amplitude and period of the sinusoid are adjustable. It is shown that worse case performance as reflected in the ROC curves occurs at the local minimum and maximum intensities of the sinusoidal nonstationarity. The ROC curves at all other points of the sinusoid oscillate between the minimum and maximum point ROC curves. The Constant False Alarm Rate (CFAR) output capability of the normalizers is also evaluated for fixed detection thresholds as the normalizers operate on the stationary and nonstationary backgrounds.

ADMINISTRATIVE INFORMATION

This memorandum was prepared under NUWC Project Number C20020, as part of the Normalizer Task of the Active Processing Initiative. The Task Leader is Fyzodeen Khan; Principal Investigator is Fyzodeen Khan, Code 3314; the NUWC program manager is James Syck, 3112 and the Program Sponsor is Howard Reichel, NAVSEA, PEO USW.

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LIST OF SYMBOLS

P(F)	Probability of False Alarm
P(D)	Probability of Detection
SNR	Signal-to-Noise Ratio
LFM	Linear Frequency Modulated
CW	Continuous Wave
λ	Detection threshold at normalizer output
Λ	Detection threshold at normalizer output in dB
σ	Rayleigh parameter of background noise variation
m_μ	Expected value of normalizer mean estimate
σ_μ^2	Variance of normalizer mean estimate

1.0 - INTRODUCTION

An analytic performance evaluation methodology is constructed to determine the performance of the Continuous Wave (CW) and Linear Frequency Modulated (LFM) waveform normalizers of the Mid-Frequency Active Classification Processor (MFACP). Performance of each normalizer is given in the form of the Receiver Operating Characteristic (ROC) curves at the normalizer output. The ROC curves quantify the single bin Probability of Detection, P(D), as a function of Signal-to-Noise Ratio, SNR, at specified Probabilities of False Alarm, P(F).

Performance of each normalizer is evaluated for stationary and nonstationary background noise conditions. The results presented here are based on the analytic evaluation methodology described in references 1 and 2. A description of the sinusoidal nonstationary noise model used for the analytic evaluation is presented in reference 1. The results show that the definitive parameters affecting normalizer performance are the mean and variance of the estimate of the noise level.

The signal processing prior to normalization consists of a Fast Fourier Transform (FFT) for CW and a matched filter for LFM followed by an envelope detector. The normalizer inputs for the noise-only and signal-plus-noise cases are Rayleigh and Rician distributed respectively.

2.0 - ANALYTIC PERFORMANCE PREDICTION

The MFACP normalizers were designed assuming stationary noise and therefore do not dynamically compensate for any variations which may occur in the noise intensity. Performance is degraded when the normalizers are required to operate in nonstationary backgrounds. The degree to which performance is degraded is dependent on the peak-to-peak amplitude variation and period for the sinusoidal noise model used in this analysis.

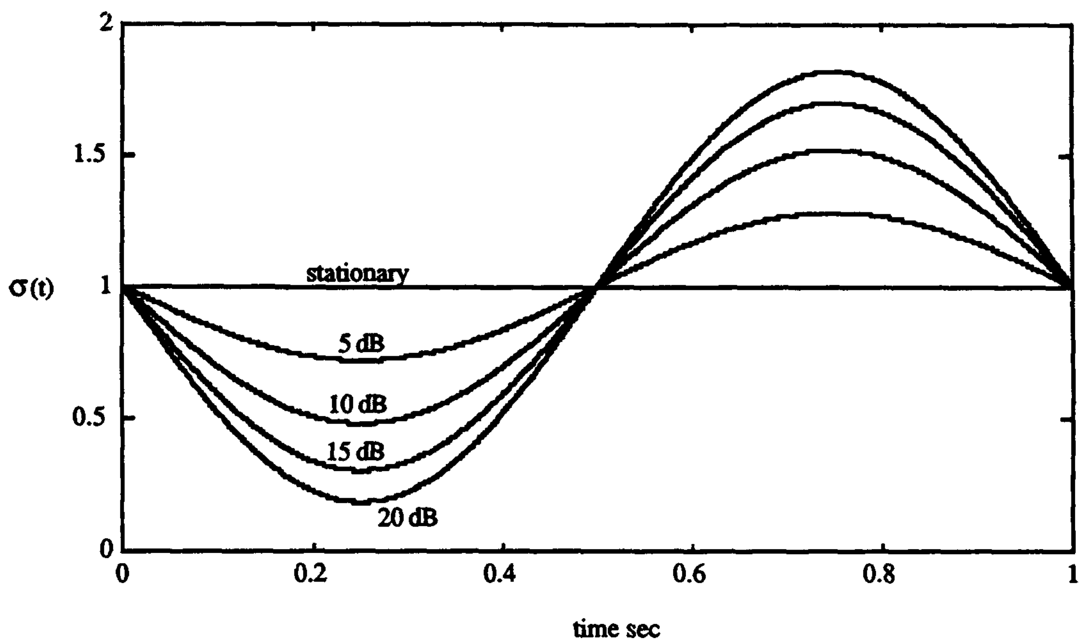
Performance in stationary noise is the optimum the normalizer can achieve in that performance in any non stationary background will be worse. In stationary noise the normalizer estimates the mean level of the test cell from identically distributed, but not necessarily independent samples, using samples from a data window surrounding the test cell. The normalized test cells in a stationary background should be equalized to an expected mean value of 1.

For nonstationary noise consider the sinusoidal model described in reference 1 where both the amplitude and period of the sinusoid are adjustable. A Rayleigh density function is characterized by a single parameter σ. The dynamic model considers a sinusoidal change in the Rayleigh parameter. To estimate the mean level of the test cell the samples surrounding the test

cell are used. Each of the surrounding cells have different noise power levels as defined by the data window σ-variation relative to the test cell of interest. The resulting normalized test cells have expected mean levels which are either greater or lower than 1 depending on the location of the test cell within the sinusoidal nonstationarity.

The normalizers were designed for a specified P(F) in stationary noise. In shallow water and convergence zones the noise can be highly nonstationary. The MFACP normalizers are fixed in their structure and not designed to adapt to nonstationary noise. The generalized sinusoidal variation of the Rayleigh parameter is designed to capture the periodic and pedestal shaped variations which may occur in shallow water or convergence zone regions respectively. This noise model is used to test how well the normalizers perform under these conditions and to determine the resulting performance degredation.

Figure (1) is a plot of $\sigma(t)$, the dynamic Rayleigh parameter which describes the sinusoidal variation of the nonstationary noise model. It shows the variation over a 1 second period for peak-to-peak amplitude changes of 5, 10, 15 and 20 dB. These dynamic variations are used to determine analytically how well both normalizers perform in this sinusoidal nonstationarity. The performance in stationary noise is used as the baseline for comparison.



Figure(1) - Plot of the Rayleigh parameter for the sinusoidal dynamic noise background variation for 4 different peak-to-peak amplitude changes and stationary noise.

There are two local extrema of the periodic variation - the maximum and minimum points of the sinusoid. As the normalizer sweeps through the sinusoid the performance varies depending on the location of the test cell. If the normalizer correctly estimates the mean level of the test cell then the normalized output value must have an expected mean level of 1 as described before. Consider the test cell when located at the local minimum. The LFM normalizer has a window structure which is symmetric about the test cell. Thus in using samples surrounding the local minimum point the normalizer over-estimates the mean level of the test cell since these samples all have a higher noise level relative to the test cell. This creates in the normalized cell an amplitude level with expected mean value less than 1. P(F) is therefore reduced but at the expense of higher required SNR for a given P(D) (equivalently, a lower P(D) at the given SNR). The ROC curve shifts to the right of the stationary ROC curve. Now consider the test cell located at the local maximum. The normalizer using the surrounding samples under-estimates the mean level of the test cell since these cells all have a lower noise level relative to the test cell. This creates a normalized test cell with an expected mean level greater than 1. This generates lower required SNR for a given P(D) but at the expense of higher P(F), i.e. a higher P(F) and P(D) occurs at the maximum. The ROC curve shifts to the left of the stationary ROC curve.

The CW normalizer has an single-sided trailing window structure where the exponential filter uses data points trailing the test cell in range. Also, there is a 4 sample delay to minimize noise window contamination by an extended target at the test cell. Thus the inherent lag in the recursive filter and the built-in 4 sample delay results in a minimum and maximum occuring at times different from the local minimum and maximum point locations of the sinusoid.

The performance still varies between a low P(D) and P(F) near the minimum and a high P(D) and high P(F) near the maximum of the sinusoidal noise model. At any other test cell location the performance oscillates between the performance at the minimum and maximum. This result is contrary to the requirement of a normalizer having a Constant False Alarm Rate (CFAR) output independent of how the background varies. This compromise in performance is due to the normalizer inability to (a) properly adapt to nonstationarity and (b) remove biases in the mean estimate which occur in nonstationary noise (assuming there is enough averaging for proper reduction of random estimation error).

The ROC curves presented later define the performance of the nomalizers in stationary noise and at the minimum and maximum of the sinusoidal nonstationarity. The variation of P(F) and P(D) over the period of the sinusoid are presented in additional figures showing how the performance of the normalizers changes as it sweeps through the nonstatonarity.

2.1 - MFACP CW NORMALIZER ANALYTIC PERFORMANCE RESULTS

Performance of the CW normalizer is determined in both stationary and nonstationary noise as described above. Table (1) is a listing of 12 threshold values and the associated P(F) under stationary noise conditions. These CFAR P(F) values which the CW normalizer was designed to meet are those corresponding to thresholds $\lambda = 3.4$, 3.9 and 4.4. Threshold $\lambda = 3.4$ is the CW tracker detect threshold after initialization, $\lambda = 3.9$ is the increment/decrement value of the Cumulative Log-Likelihood Ratio (CLLR) and $\lambda = 4.4$ is the tracker initialization threshold.

Threshold λ	Threshold Λ (dB)	P(F) (Hanning)
1.9	5.5751	6.16040×10^{-02}
2.4	7.6042	1.22639×10^{-02}
2.9	9.2480	1.75489×10^{-03}
3.4	10.630	1.85219×10^{-04}
3.9	11.821	1.48378×10^{-05}
4.4	12.869	9.30244×10^{-07}
4.9	13.804	4.71133×10^{-08}
5.4	14.648	1.99041×10^{-09}
5.9	15.417	7.24058×10^{-11}
6.4	16.124	2.33875×10^{-12}
6.9	16.777	6.90696×10^{-14}
7.4	17.385	1.91682×10^{-15}

Table (1) - Predicted P(F) as a function of threshold (λ, Λ in dB) for the MFACP CW normalizer in stationary noise.

Figure (2) show plots of the expected value and variance of the CW normalizer mean estimate as determined by equations 3-16 and 3-18 of reference 1. The expected value, m_μ, and variance, σ_μ^2, of the noise mean estimate of the test cell for both stationary and nonstationary noise is shown. Reference 1 shows that for the recursive structure of the CW normalizer, there are 17 effective independent samples per Doppler channel. After block averaging 5 Doppler channels centered on the channel in which the test cell is located the normalizer possesses a figure of 85 independent samples that go into the estimate of the mean. This provides sufficient averaging for reduction of the random estimation error. The figure shows that there is a bias in

the estimate of the mean even und:: stationary noise conditions. The figure also shows the bias lag in the mean estimate for th sinusoidal noise model. For stationary noise with $\sigma = 1$, the true mean value of the test cell is $\mu = \sqrt{\pi/2}$. The expected value of the normalizer estimate is m_μ = 1.2516; the bias in the estimate is therefore 1.714×10^{-3}. The variance of the estimate is 4.9345×10^{-3} In the case of the ideal normalizer (defined by perfect estimation of the test cell noise me_n) the expected value of the mean estimate is equal to the true mean and the variance of the estimate is therefore zero.

Figure (3) shows the ratio of the expected value of the mean estimate to the Rayleigh parameter and the ratio of the variance of the mean estimate to the square of the Rayleigh parameter. These ratios are sufficient statistics utilized in the P(F) and P(D) equations (2-7) and (2-8) given in reference 1. The minimum and maximum points on these graphs are the points where worse case degradation in performance would occur as described previously. Note the minimum and maximum are slightly different from the local minimum and maximum, respectively, of the sinusoid as discussed previously.

Figure (4) compares the performance of the CW normalizer in stationary noise to the theoretically ideal normalizer performance at 3 different P(F) values. The difference in the ROC curves are due to the bias and non zero variance of the mean estimate.

Figures (5) - (7) shows the ROC curves for the CW normalizer for λ = 3.4, 3.9 and 4.4 at the 4 different noise amplitude variations. For example, figure (7d) contains the stationary, maximum and minimum ROC curves for a 20 dB amplitude sinusoid variation over 1 second. The corresponding P(F) for stationary noise is 1.85219×10^{-4} at $\lambda = 3.4$. P(F) at the minimum and maximum for $\lambda = 3.4$ is 4.4954×10^{-6} and 1.7950×10^{-3} respectively. The caption in each of the figures lists the specific parameters. Inspection of the figures shows that as the amplitude of the dynamic noise increases the ROC curves corresponding to the minimum and maximum moves further to the right and left of the stationary and ideal ROC curves respectively as described earlier.

The ROC curves described above show only the maximum deviation away from the stationary and ideal ROC curves as the normalizer sweeps through the sinusoidal variation. Figures (8) - (11) show the variation in P(F) and SNR, at P(D) = 0.5, and 0.9 for each of the 4 sinusoidal noise amplitudes and each of the 3 thresholds. These curves quantify the MFACP CW normalizer performance for the given noise nonstationarity model and the P(D) = 0.5 and 0.9 requirement. As the normalizer moves through the sinusoid the P(F) is not maintained. At the minimum noise variation point P(F) is lower than the designed P(F) (the stationary noise value) but the SNRs required for P(D) = 0.5 and 0.9 are higher. At the maximum noise variation point P(F) is higher but the required SNRs for P(D) = 0.5 and 0.9 are lower. Thus, at the minimum noise variation point the P(F) performance is better than the design requirement but the

P(D) performance is worse since a larger SNR is required; at the maximum noise variation point, the P(F) performance is worse than the design value but the P(D) performance is better.

2.2 - MFACP FM NORMALIZER ANALYTIC PERFORMANCE RESULTS

Performance of the MFACP FM normalizer is determined in both stationary and non stationary noise. Table (2) is a listing of 12 threshold values and the associated P(F) under stationary noise conditions. These CFAR P(F) values which the FM normalizer was designed to meet are those corresponding to thresholds Of particular interest are thresholds $\lambda = 3.0$, 3.5 and 4.0. $\lambda = 3.0$ is the MFACP FM tracker detect threshold after initialization; $\lambda = 3.5$ is the increment/decrement value of the Cumulative Log-Likelihood Ratio (CLLR) and $\lambda = 4.0$ is the tracker initialization threshold.

Figure (12) shows plots of the expected value and variance of the FM normalizer mean estimate as determined in reference 2. The expected value of the mean estimate is compared to the true mean showing the bias in the estimate as the FM normalizer sweeps through the dynamic background. In the case of the ideal normalizer the expected value of the mean estimate is equal to the true mean and the variance of the estimate is therefore zero. Figure (13) shows plots of the ratio of the expected value of the mean estimate to the Rayleigh parameter and the ratio of the variance of the mean estimate to the square of the Rayleigh parameter.

Figure (14) compares the performance of the FM normalizer in stationary noise to the theoretically ideal normalizer performance at 3 different P(F) values. The differences in the ROC curves are due to the bias and the non zero variance of the noisemean estimate.

Figures (15) - (17) show the ROC curves for the FM normalizer for $\lambda = 3.0$, 3.5 and 4.0 at the 4 different noise amplitude variations. For example, figure (17d) gives the stationary, maximum and minimum ROC curves for a 20 dB amplitude sinusoid variation over 1 second. The corresponding P(F) for stationary noise is 2.0587×10^{-3} at $\lambda = 3.0$. P(F) at the minimum and maximum noise variation points for $\lambda = 3.0$ is 1.6267×10^{-9} and 6.5345×10^{-3} respectively. The caption in each of the figures lists the specific parameters. Inspection of the figures show that as the amplitude of the dynamic noise increases the ROC curves corresponding to the minimum and maximum noise variation points moves further to the right and left of the stationary and ideal ROC curve respectively.

Threshold λ	Threshold Λ (dB)	P(F)
1.5	3.5218	1.9440×10^{-01}
2.0	6.0206	5.6828×10^{-02}
2.5	7.9588	1.2332×10^{-02}
3.0	9.5424	2.0587×10^{-03}
3.5	10.881	2.7488×10^{-04}
4.0	12.041	3.0573×10^{-05}
4.5	13.064	2.9493×10^{-06}
5.0	13.979	2.5653×10^{-07}
5.5	14.807	2.0858×10^{-08}
6.0	15.563	1.6376×10^{-09}
6.5	16.258	1.2776×10^{-10}
7.0	16.902	1.0149×10^{-11}

Table (2) - Predicted P(F) as a function of threshold (λ, Λ in dB) for the MFACP FM normalizer in stationary noise.

The ROC curves described above show only the maximum deviation away from the stationary and ideal ROC curves as the normalizer sweeps through the sinusoidal variation. Figures (18) - (21) show the variation in P(F) and SNR, at P(D) = 0.5 and 0.9, for each of the 4 sinusoidal noise amplitudes and each of the 3 thresholds. These curves quantify the MFACP FM normalizer performance for the given noise nonstationarity model and the P(D) = 0.5 and 0.9 requirement. As the normalizer moves through the sinusoid the P(F) is not maintained. At the minimum noise variation point P(F) is lower than the design P(F) requirement (the stationary noise value) but the SNRs required for P(D) = 0.5 and 0.9 are higher. At the maximum noise variation point P(F) is higher but the required SNRs for P(D) = 0.5 and 0.9 are lower. Thus, at the minimum the P(F) performance is better than the design requirement but the P(D) performance is worse since a larger SNR is required; at the maximum noise variation point, the P(F) performance is worse than the design value but the P(D) performance is better.

3.0 - CONCLUSIONS

An analytic evaluation methodology was used to determine the performance of the MFACP normalizers. The single bin P(F) and P(D) performances at the normalizer output, expressed rigorously in the ROC curves, are determined for both stationary and non stationary noise. The non stationary noise model assumes a periodic variation of the noise cell power with arbitrary amplitude and period.

The results presented showed that neither the CW nor the FM normalizer maintain a CFAR output in nonstaionary noise backgrounds. The variation in P(F) for the different dynamic noise backgrounds are given in figures (8) - (11) for the CW normalizer and (18) - (21) for the FM normalizer. These figures also show the change in required SNR at the normalizer input needed to maintain the desired P(D) = 0.5, 0.9. Figures (22) and (23) show the variation of P(F) as a function of threshold in stationary noise and at the minimum and maximum points of the sinusoidal noise variation. Figures (24) and (25) show the variation of SNR as a function of threshold in stationary noise and at the minimum and maximum points of the sinusoidal noise variation. These figures clearly show that a CFAR output is not achieved.

The non-CFAR outputs of the normalizers are a direct consequence of the non adaptive nature of the algorithms. The algorithms as presently implemented do not allow for dynamic compensation of the background as necessary to generate an equalized output power level in all test cells. This results in either higher or lower P(F) than the P(F) design requirement at the normalizer output.

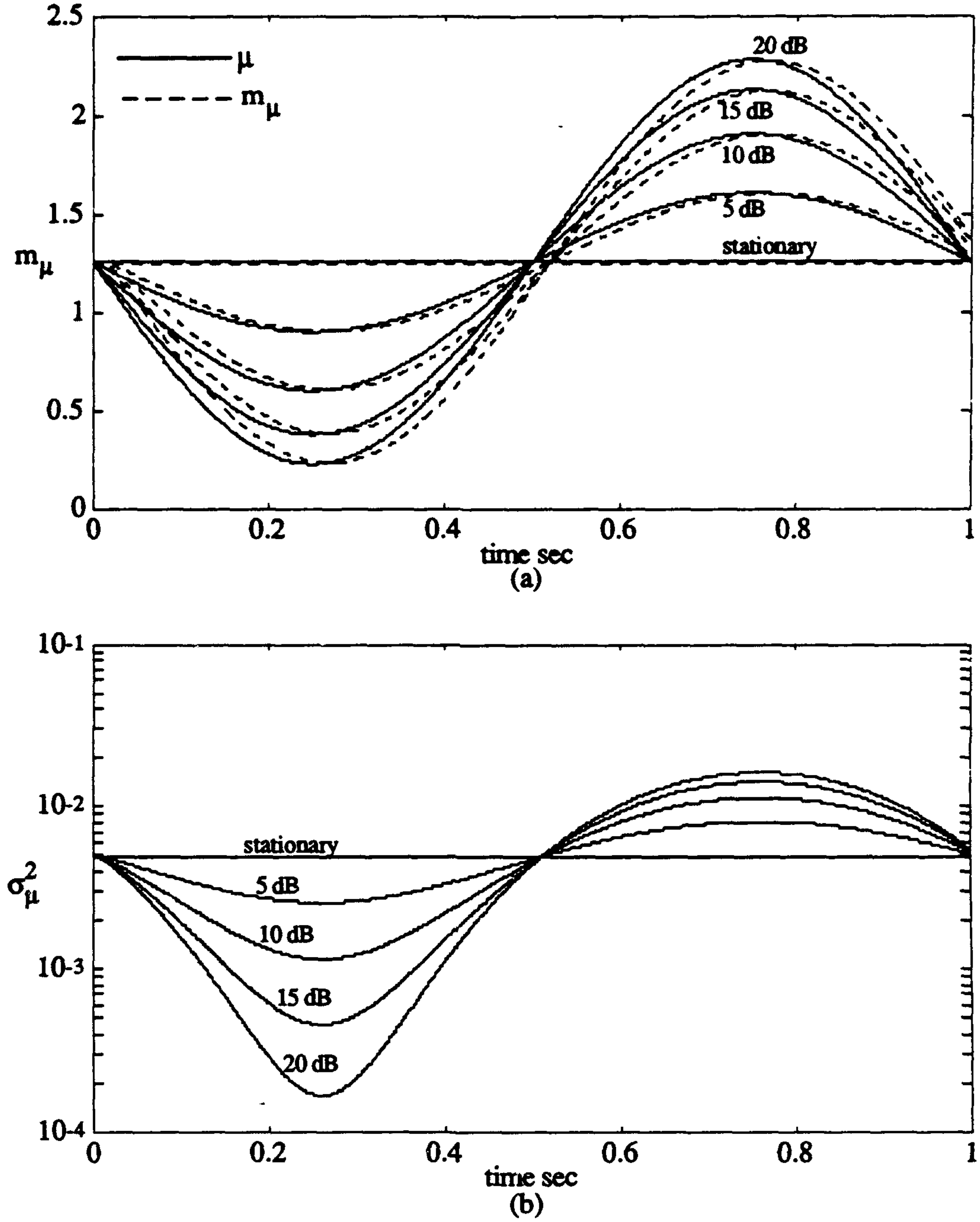


Figure (2) - Variation of the expected value of the CW normalizer mean estimate compared to the true mean and the variance of the mean estimate for stationary noise and sinusoidal peak-to-peak noise amplitude variations of 5, 10, 15 and 20 dB. Under ideal conditions the estimate and variance equals $(\pi/2)^{1/2}$ and 0 respectively. For stationary noise the expected value and variance of the mean estimate are 1.25163 and 4.93446×10^{-3} respectively. The difference between the true and estimated mean is the bias created by the normalizer which along with the variance of the estimate accounts for the degradation in normalizer performance.

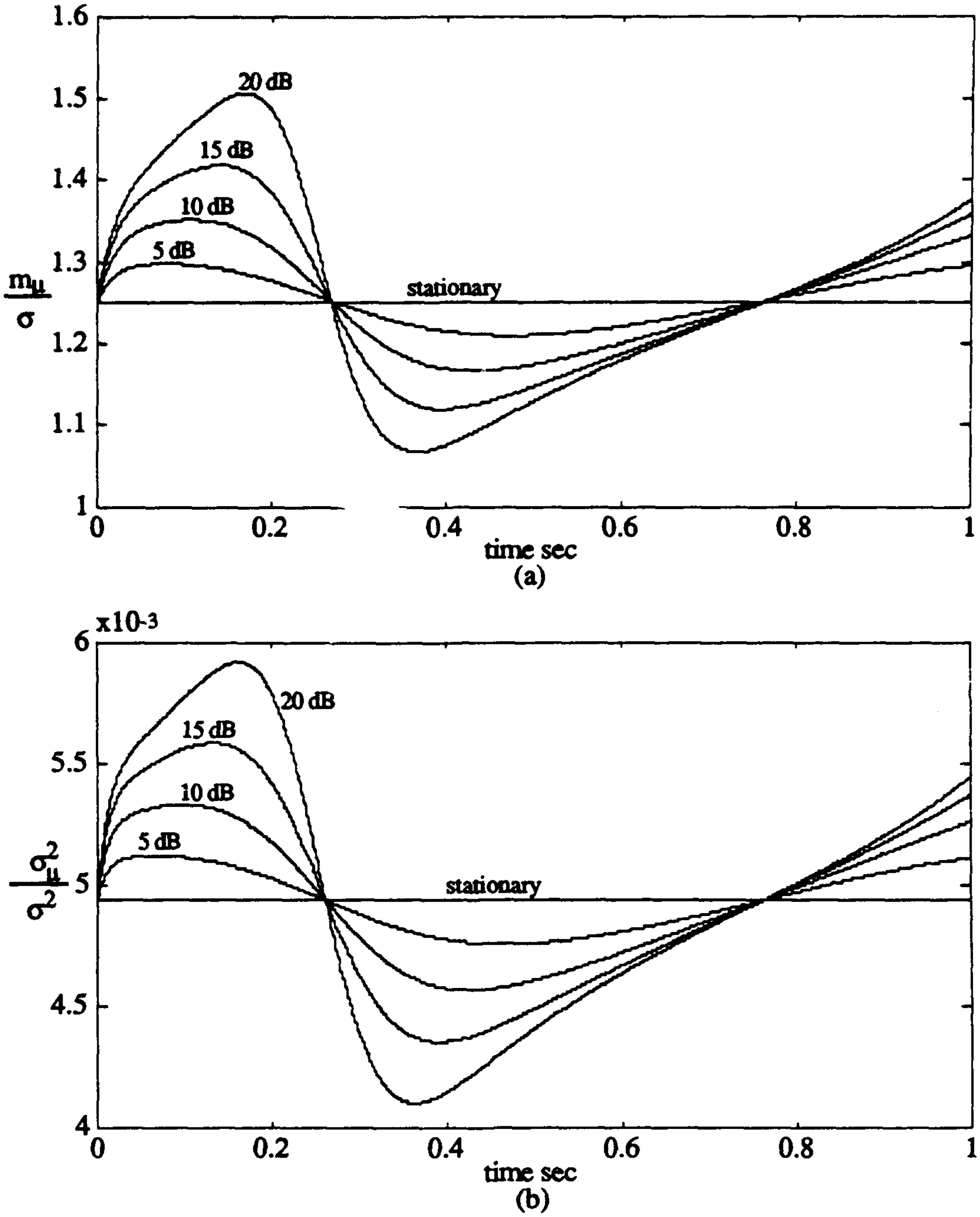


Figure (3) - Variation of the ratio of the expected value and variance of the estimated mean to true σ of the test cell being normalized for the 4 sinusoidal noise amplitudes for CW normalizer. For an unbiased normalizer the ratio of the expected value of the mean estimate to σ is $(\pi/2)^{1/2}$. The bias in the mean estimation causes degredation in normalizer performance. The 85 effective independent samples in the estimate provides enough random error reduction of the mean estimate.

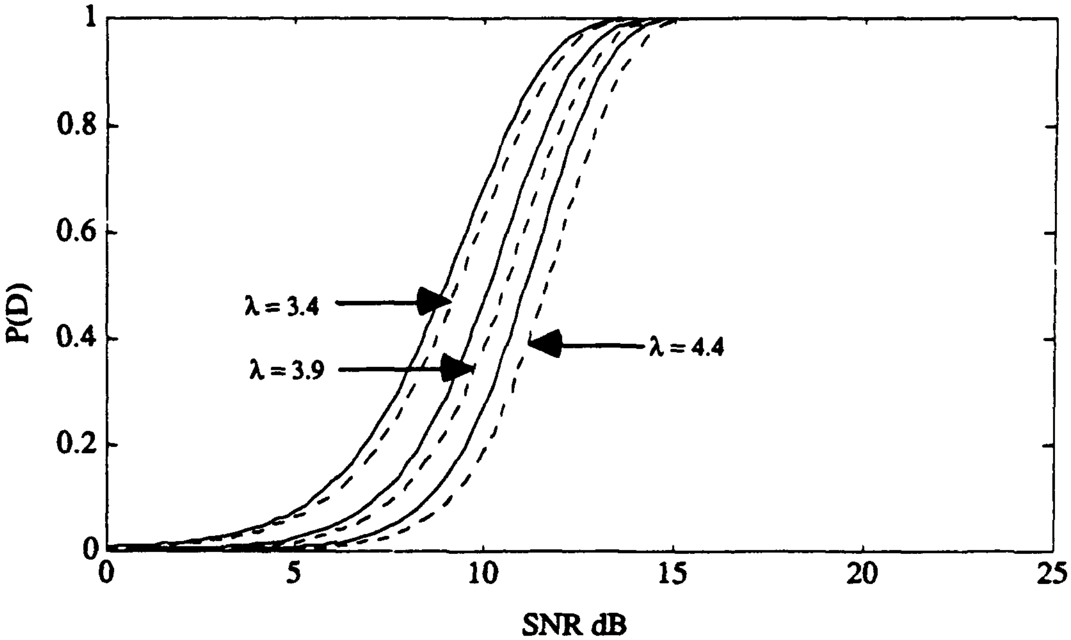


Figure (4) - Comparison of the theoretically ideal ROC curves to the ROC curves in stationary noise at thresholds $\lambda = \{3.4, 3.9, 4.4\}$. The theoretical ROC curve assumes the mean value of the noise is known exactly, i.e. it is a deterministic quantity. The ROC curves for the stationary noise are shifted to the left of the theoretical due to both the bias and the variance associated with the mean estimate. The P(F) associated to these curves are $\{1.85219 \times 10^{-04}, 1.48378 \times 10^{-05}, 9.30244 \times 10^{-07}\}$. The optimum performance of the CW normalizer is given by the stationary noise ROC curves and are used in the figures following to compare performance under nonstationary noise conditions.

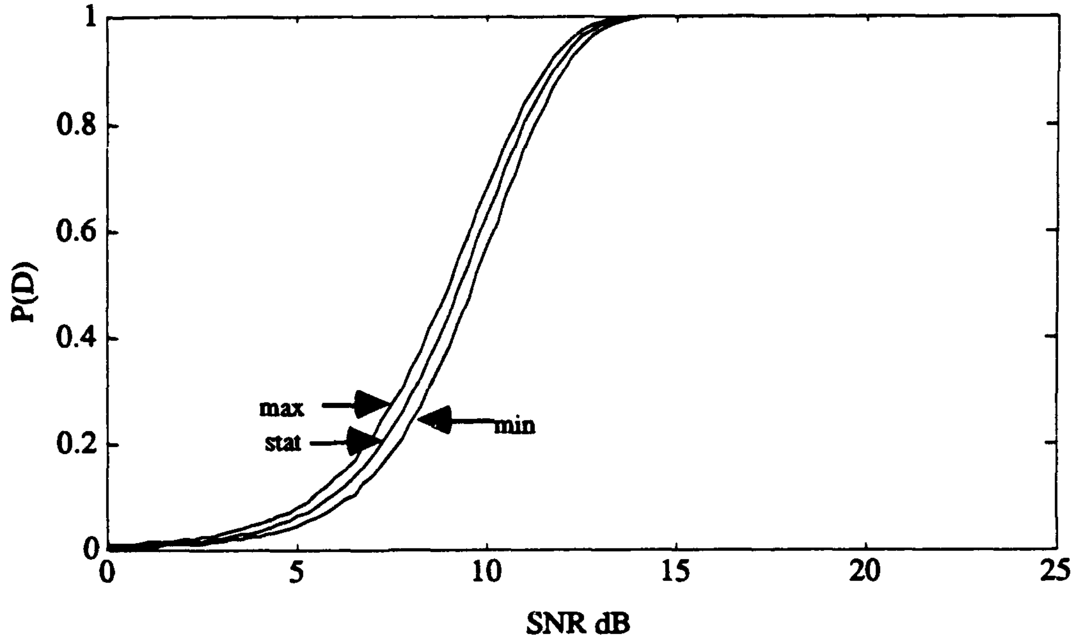


Figure (5a) - ROC curves at the output of the CW normalizer. The curves depict performance for stationary noise and at the minimum and maximum of the sinusoidal variation. The sinusoid has a 5 dB peak-to-peak variation with a 1 sec. period. The detection threshold is set to $\lambda = 3.4$. P(F) for stationary noise is 1.85219×10^{-4}; at the minimum and maximum P(F) are 9.8532×10^{-5} and 3.1811×10^{-4} respectively. At P(D) = {0.5, 0.9} the required SNRs are {9.66, 12.00} and 9.01, 11.52} at the minimum and maximum respectively. For stationary noise the required SNRs are {9.32, 11.75} dB at P(D) = {0.5, 0.9}.

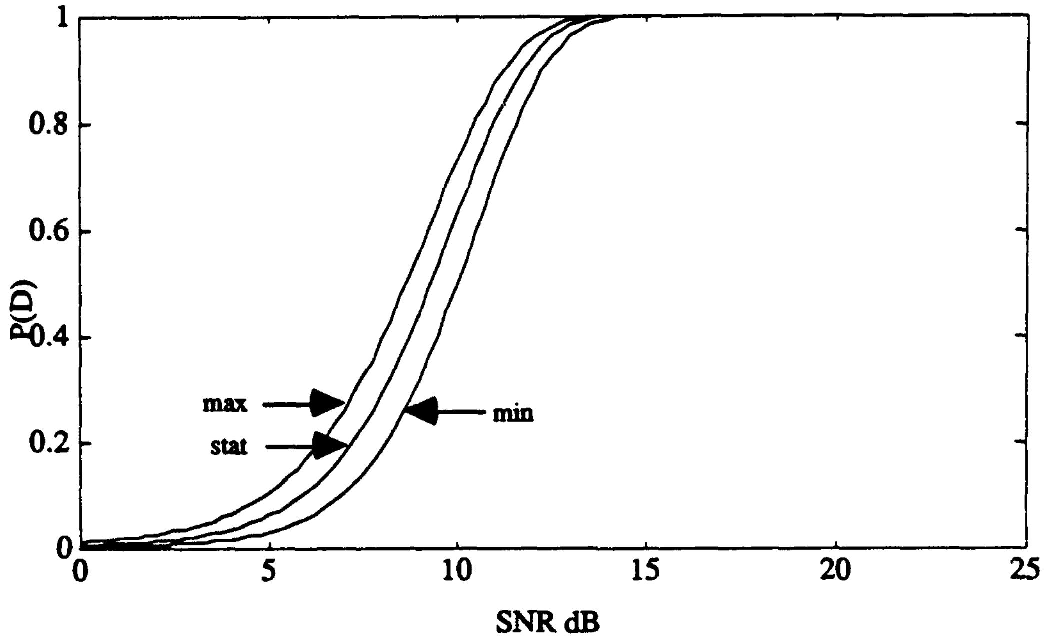


Figure (5b) - ROC curves at the output of the CW normalizer. The curves depict performance for stationary noise and at the minimum and maximum of the sinusoidal variation. The sinusoid has a 10 dB peak-to-peak variation with a 1 sec. period. The detection threshold is set to $\lambda = 3.4$. P(F) for stationary noise is 1.85219×10^{-4}; at the minimum and maximum P(F) are 4.6281×10^{-5} and 5.5220×10^{-4} respectively. At P(D) = {0.5, 0.9} the required SNRs are {10.03, 12.20} and {8.67, 11.26} at the minimum and maximum respectively. For stationary noise the required SNRs are {9.32, 11.75} dB at P(D) = {0.5, 0.9

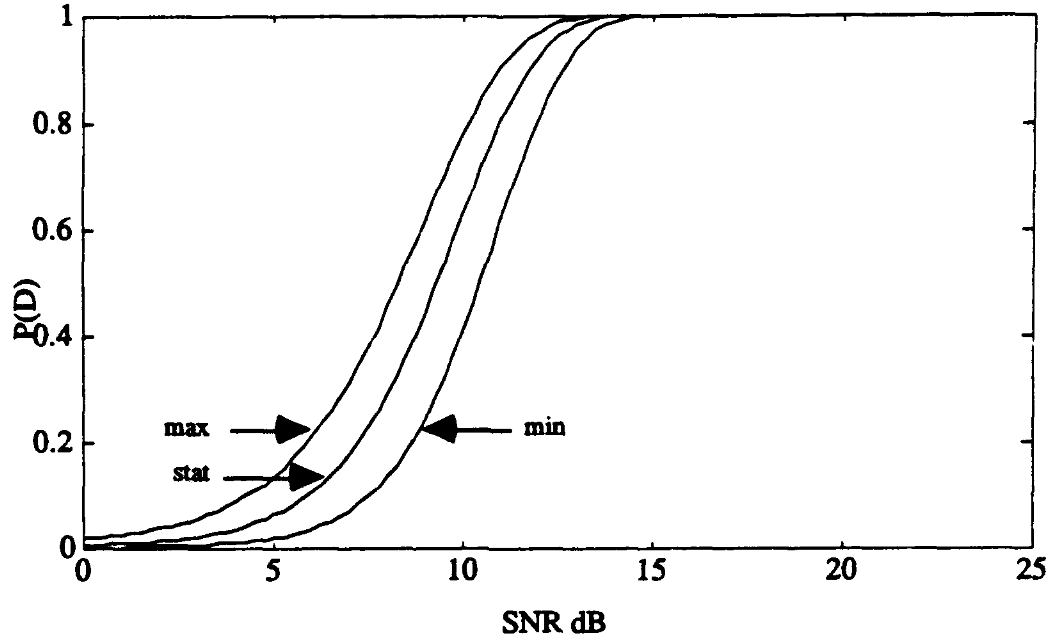


Figure (5c) - ROC curves at the output of the CW normalizer. The curves depict performance for stationary noise and at the minimum and maximum of the sinusoidal variation. The sinusoid has a 15 dB peak-to-peak variation with a 1 sec. period. The detection threshold is set to $\lambda = 3.4$. P(F) for stationary noise is 1.85219×10^{-4}; at the minimum and maximum P(F) are 1.7479×10^{-5} and 9.7705×10^{-4} respectively. At P(D) = {0.5, 0.9} the required SNRs are {10.46, 12.63} and {8.29, 10.98} at the minimum and maximum respectively. For stationary noise the required SNRs are {9.32, 11.75} dB at P(D) = {0.5, 0.9}.

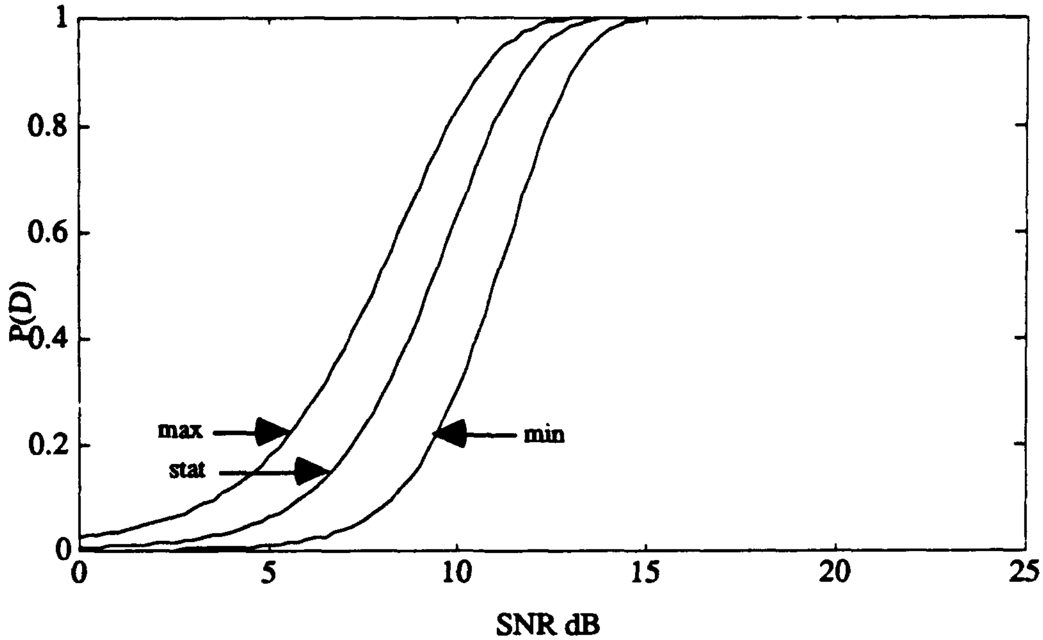


Figure (5d) - ROC curves at the output of the CW normalizer. The curves depict performance for stationary noise and at the minimum and maximum of the sinusoidal variation. The sinusoid has a 20 dB peak-to-peak variation with a 1 sec. period. The detection threshold is set to $\lambda = 3.4$. P(F) for stationary noise is 2.181×10^{-4}; at the minimum and maximum P(F) are 4.9454×10^{-6} and 1.7950×10^{-3} respectively. At P(D) = {0.5, 0.9} the required SNRs are {11.01, 13.06} and {7.85, 10.66} at the minimum and maximum respectively. For stationary noise the required SNRs are {9.32, 11.75} dB at P(D) = {0.5, 0.9}.

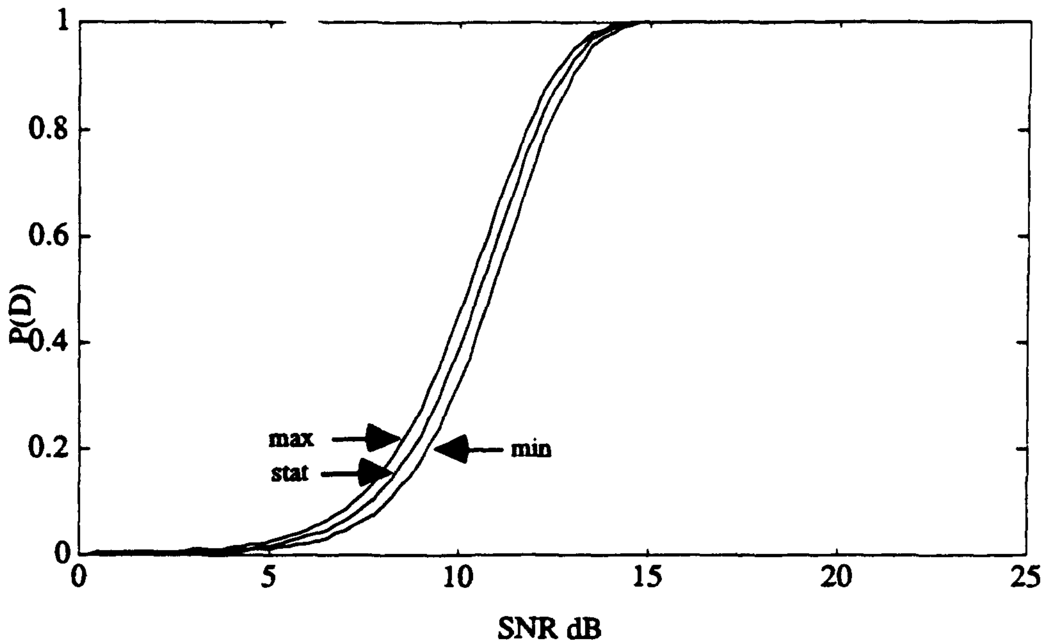


Figure (6a) - ROC curves at the output of the CW normalizer. The curves depict performance for stationary noise and at the minimum and maximum of the sinusoidal variation. The sinusoid has a 5 dB peak-to-peak variation with a 1 sec. period. The detection threshold is set to $\lambda = 3.9$. P(F) for stationary noise is 1.48378×10^{-5}; at the minimum and maximum P(F) are 6.5881×10^{-6} and 2.9692×10^{-5} respectively. At P(D) = {0.5, 0.9} the required SNRs are {10.90, 12.98} and {10.27, 12.48} at the minimum and maximum respectively. For stationary noise the required SNRs are {10.57, 12.72} dB at P(D) = {0.5, 0.9}.

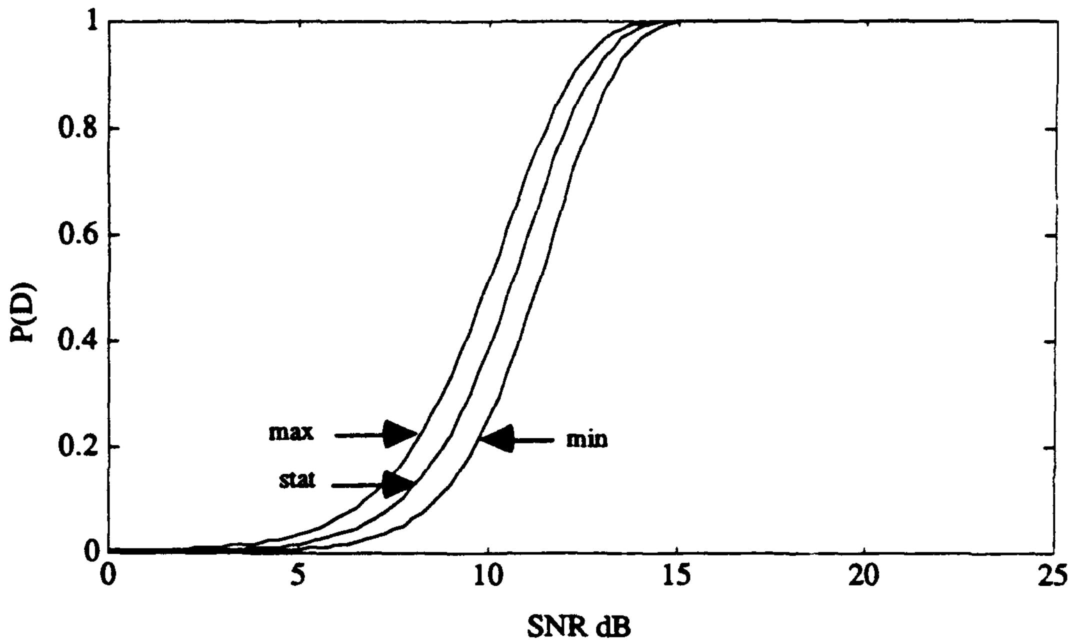


Figure (6b) - ROC curves at the output of the CW normalizer. The curves depict performance for stationary noise and at the minimum and maximum of the sinusoidal variation. The sinusoid has a 10 dB peak-to-peak variation with a 1 sec. period. The detection threshold is set to $\lambda = 3.9$. P(F) for stationary noise is 1.48378×10^{-5}; at the minimum and maximum P(F) are 2.5074×10^{-6} and 6.0270×10^{-5} respectively. At P(D) = {0.5, 0.9} the required SNRs are {11.27, 13.28} and {9.93, 12.23} at the minimum and maximum respectively. For stationary noise the required SNRs are {10.57, 12.72} dB at P(D) = {0.5, 0.9}.

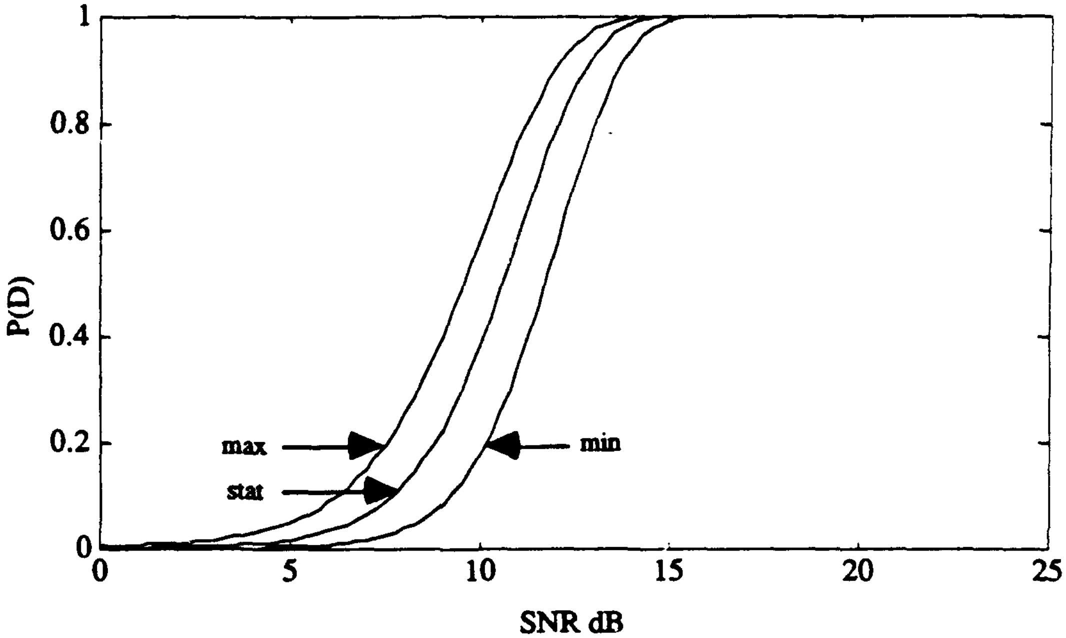


Figure (6c) - ROC curves at the output of the CW normalizer. The curves depict performance for stationary noise and at the minimum and maximum of the sinusoidal variation. The sinusoid has a 15 dB peak-to-peak variation with a 1 sec. period. The detection threshold is set to $\lambda = 3.9$. P(F) for stationary noise is 1.48378×10^{-5}; at the minimum and maximum P(F) are 7.2071×10^{-7} and 1.2543×10^{-4} respectively. At P(D) = {0.5, 0.9} the required SNRs are {11.70, 13.62} and {9.56, 11.94} at the minimum and maximum respectively. For stationary noise the required SNRs are {10.57, 12.72} dB at P(D) = {0.5, 0.9}.

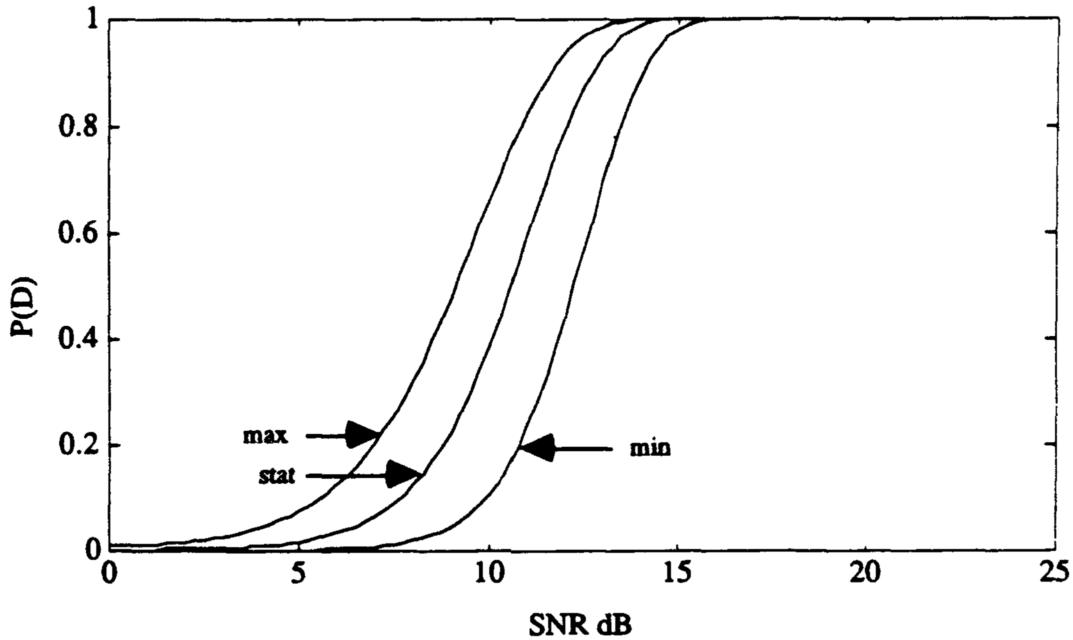


Figure (6d) - ROC curves at the output of the CW normalizer. The curves depict performance for stationary noise and at the minimum and maximum of the sinusoidal variation. The sinusoid has a 20 dB peak-to-peak variation with a 1 sec. period. The detection threshold is set to $\lambda = 3.9$. P(F) for stationary noise is 1.48378×10^{-5}; at the minimum and maximum P(F) are 1.2692×10^{-7} and 2.7407×10^{-4} respectively. At P(D) = {0.5, 0.9} the required SNRs are {12.24, 14.06} and {9.13, 11.61} at the minimum and maximum respectively. For stationary noise the required SNRs are {10.57, 12.72} dB at P(D) = {0.5, 0.9}.

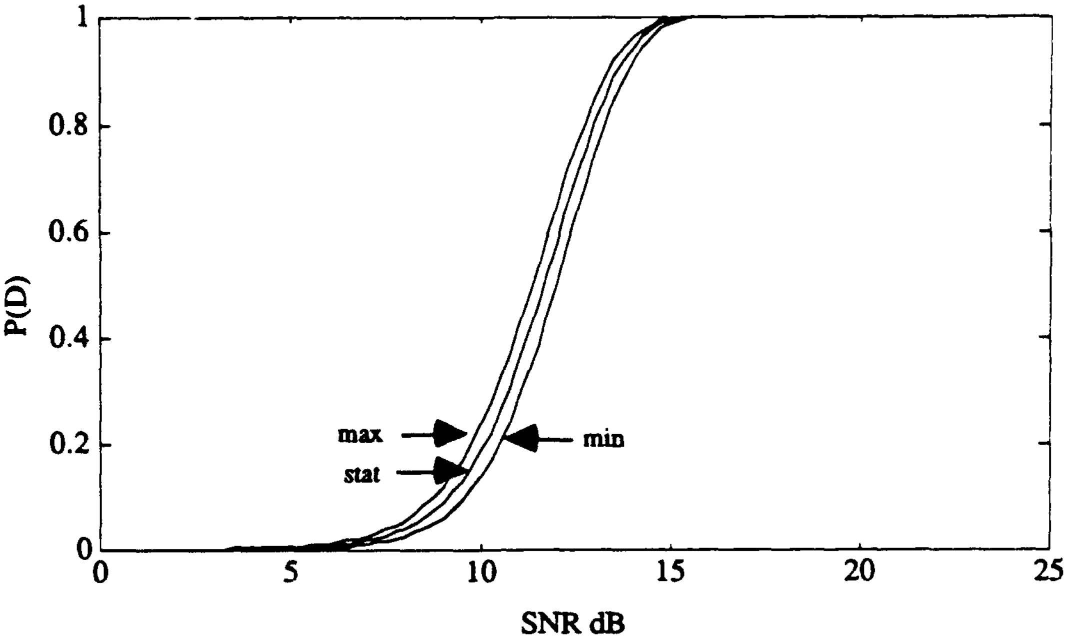


Figure (7a) - ROC curves at the output of the CW normalizer. The curves depict performance for stationary noise and at the minimum and maximum of the sinusoidal variation. The sinusoid has a 5 dB peak-to-peak variation with a 1 sec. period. The detection threshold is set to $\lambda = 4.4$. P(F) for stationary noise is 9.30244×10^{-7}; at the minimum and maximum P(F) are 3.4066×10^{-7} and 2.1943×10^{-6} respectively. At P(D) = {0.5, 0.9} the required SNRs are {11.99, 13.86} and {11.36, 13.34} at the minimum and maximum respectively. For stationary noise the required SNRs are {11.66, 13.59} dB at P(D) = {0.5, 0.9}.

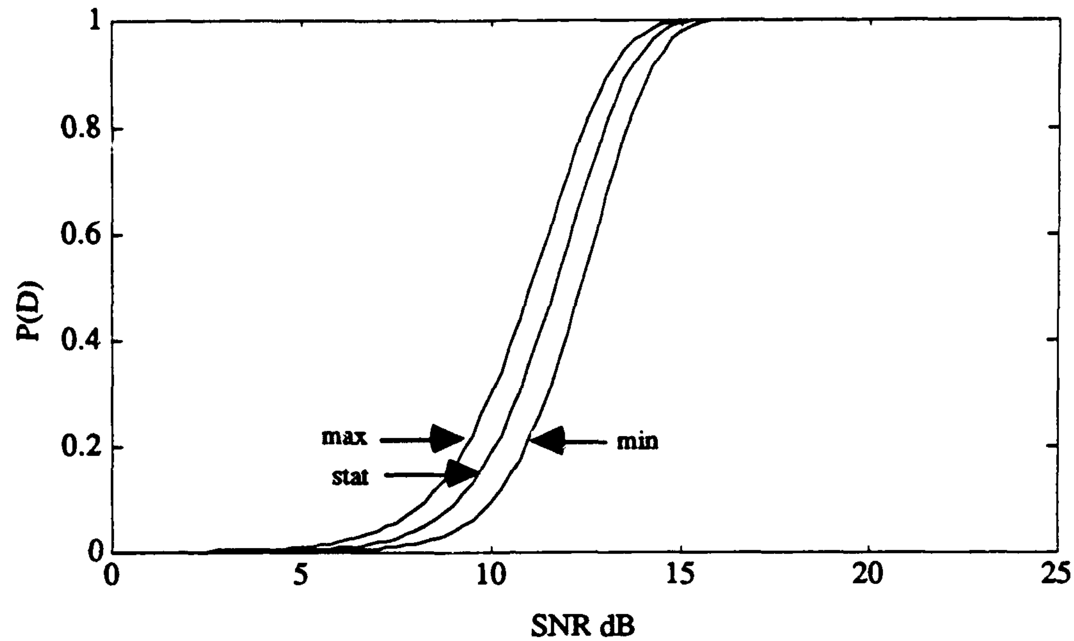


Figure (7b) - ROC curves at the output of the CW normalizer. The curves depict performance for stationary noise and at the minimum and maximum of the sinusoidal variation. The sinusoid has a 10 dB peak-to-peak variation with a 1 sec. period. The detection threshold is set to $\lambda = 4.4$. P(F) for stationary noise is 9.30244×10^{-7}; at the minimum and maximum P(Γ) are 1.0322×10^{-7} and 5.2728×10^{-6} respectively. At P(D) = {0.5, 0.9} the required SNRs are {12.35, 14.16} and {11.03, 13.01} at the minimum and maximum respectively. For stationary noise the required SNRs are {11.66, 13.59} dB at P(D) = {0.5, 0.9}.

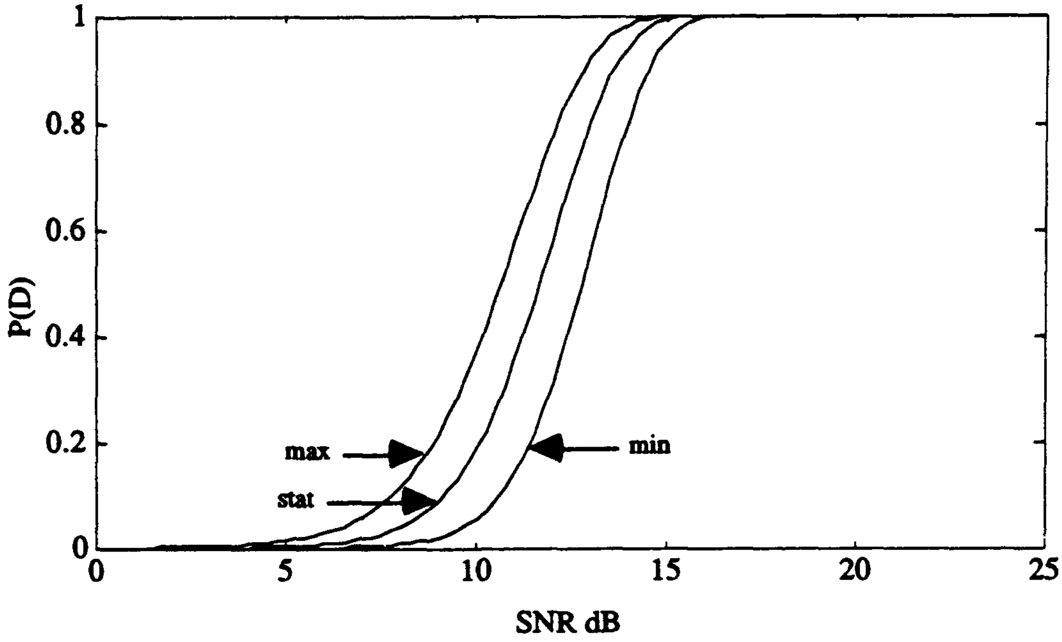


Figure (7c) - ROC curves at the output of the CW normalizer. The curves depict performance for stationary noise and at the minimum and maximum of the sinusoidal variation. The sinusoid has a 15 dB peak-to-peak variation with a 1 sec. period. The detection threshold is set to $\lambda = 4.4$. P(F) for stationary noise is 9.30244×10^{-7}; at the minimum and maximum P(F) are 2.2135×10^{-8} and 1.3074×10^{-5} respectively. At P(D) = {0.5, 0.9} the required SNRs are {12.78, 14.51} and {11.03, 13.01} at the minimum and maximum respectively. For stationary noise the required SNRs are {10.66, 12.80} dB at P(D) = {0.5, 0.9}.

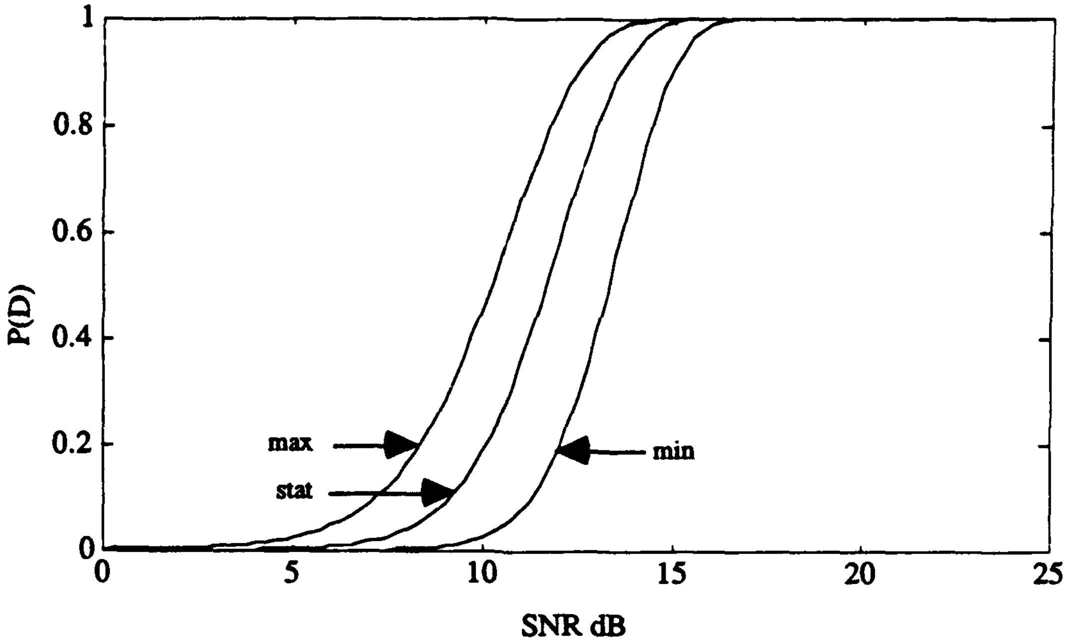


Figure (7d) - ROC curves at the output of the CW normalizer. The curves depict performance for stationary noise and at the minimum and maximum of the sinusoidal variation. The sinusoid has a 20 dB peak-to-peak variation with a 1 sec. period. The *detection threshold is set to* λ = 4.4. P(F) for stationary noise is 9.30244×10^{-7}; at the minimum and maximum P(F) are 2.5993×10^{-9} and 3.4459×10^{-5} respectively. At P(D) = {0.5, 0.9} the required SNRs are {13.32, 14.96} and {10.23, 12.46} at the minimum and maximum respectively. For stationary noise the required SNRs are {10.66, 12.80} dB at P(D) = {0.5, 0.9}.

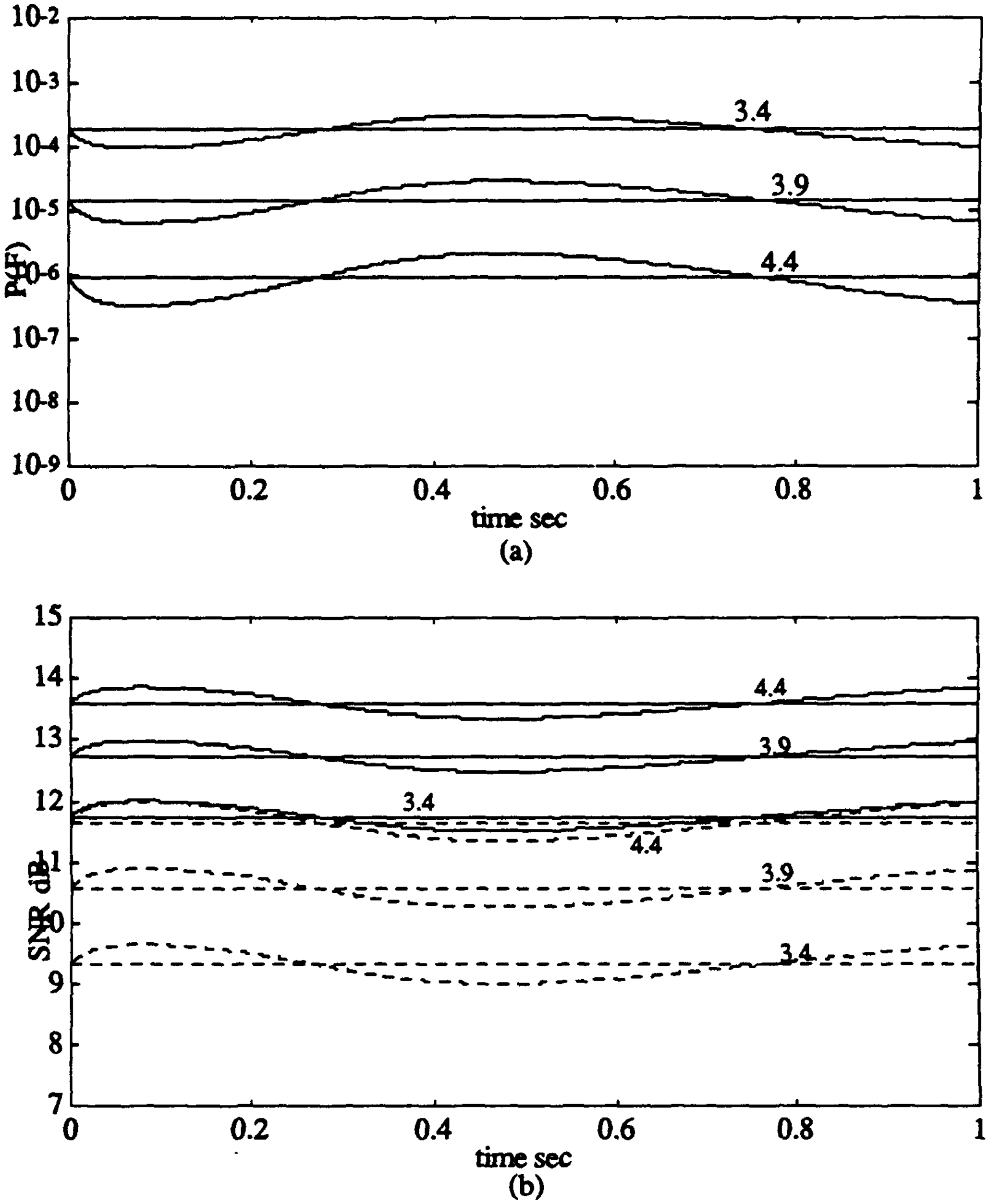


Figure (8) - Variation of P(F) and SNR for P(D) = 0.5 and 0.9 at $\lambda = \{3.4, 3.9, 4.4\}$ at the CW normalizer output for a sinusoidal noise amplitude variation is 5 dB over 1 sec. As the normalizer sweeps through the sinusoid P(F) decreases to $\{9.8532\text{x}10^{-5}, 6.5881\text{x}10^{-6}, 3.4066\text{x}10^{-7}\}$ and then increases to $\{3.1811\text{x}10^{-4}, 2.9692\text{x}10^{-5}, 2.1943\text{x}10^{-6}\}$; the SNR (at P(D) = 0.5, 0.9) increases to {9.66, 10.90, 11.99} and {12.00, 12.98, 13.86} and then decreases to {9.01, 10.27, 11.36} and {11.52, 12.48, 13.34} respectively. In stationary noise, P(F) = $\{1.8522\text{x}10^{-4}, 1.4838\text{x}10^{-5}, 9.3024\text{x}10^{-7}\}$; SNR = {9.32, 10.57, 11.66} and {11.75, 12.72, 13.59}.

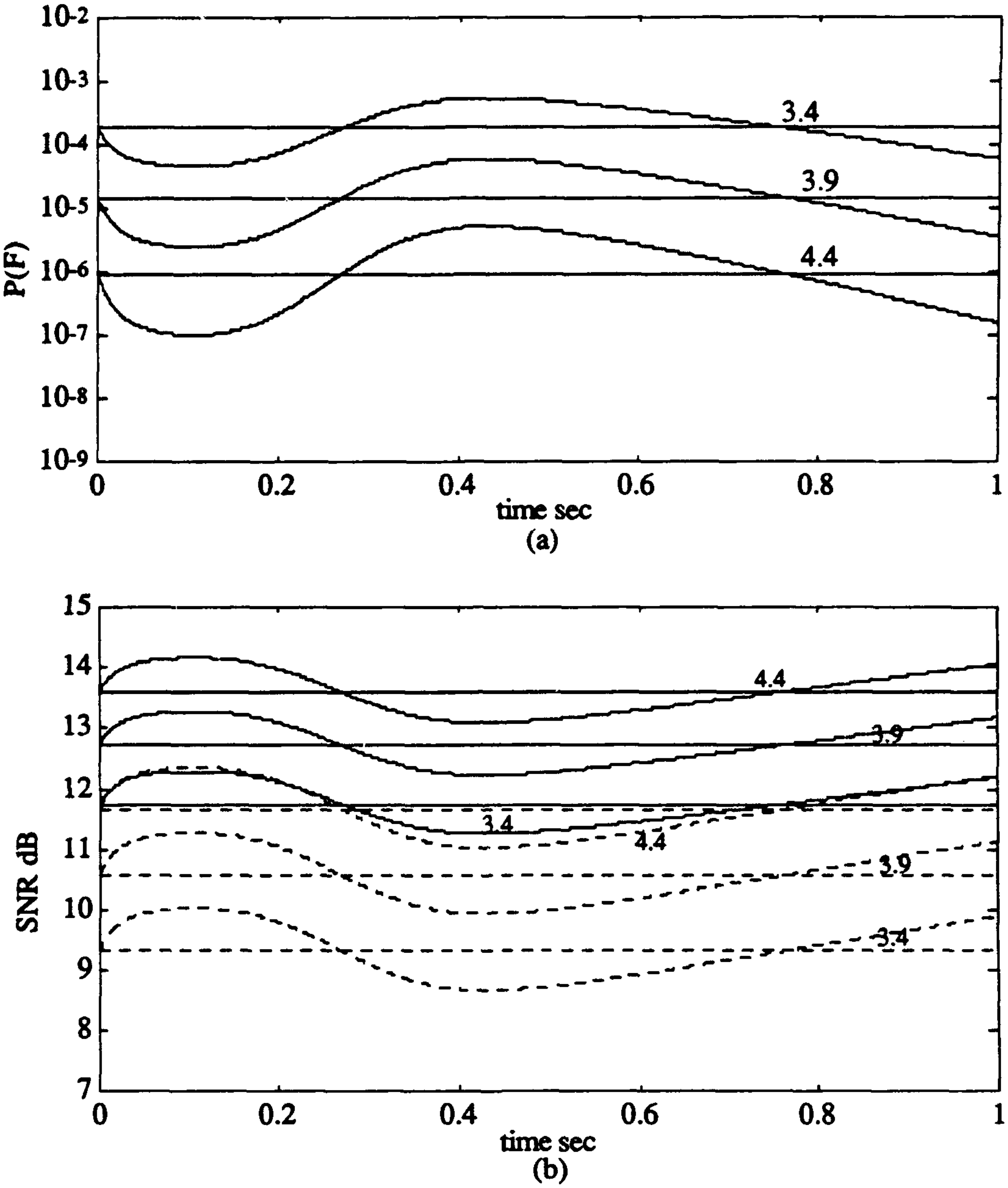


Figure (9) - Variation of P(F) and SNR for P(D) = 0.5 and 0.9 at $\lambda = \{3.4, 3.9, 4.4\}$ at the CW normalizer output for a sinusoidal noise amplitude variation is 10 dB over 1 sec. As the normalizer sweeps through the sinusoid P(F) decreases to $\{4.6281\times10^{-5}, 2.5074\times10^{-6}, 1.0322\times10^{-7}\}$ and then increases to $\{5.5220\times10^{-4}, 6.0270\times10^{-5}, 5.2728\times10^{-6}\}$; the SNR (at P(D) = 0.5, 0.9) increases to {10.03, 11.27, 12.35} and {12.29, 13.28, 14.16} and then decreases to {8.67, 9.93, 11.03} and {11.26, 12.23, 13.01} respectively. In stationary noise, P(F) = $\{1.8522\times10^{-4}, 1.4838\times10^{-5}, 9.3024\times10^{-7}\}$; SNR = {9.32, 10.57, 11.66} and {11.75, 12.72, 13.59}.

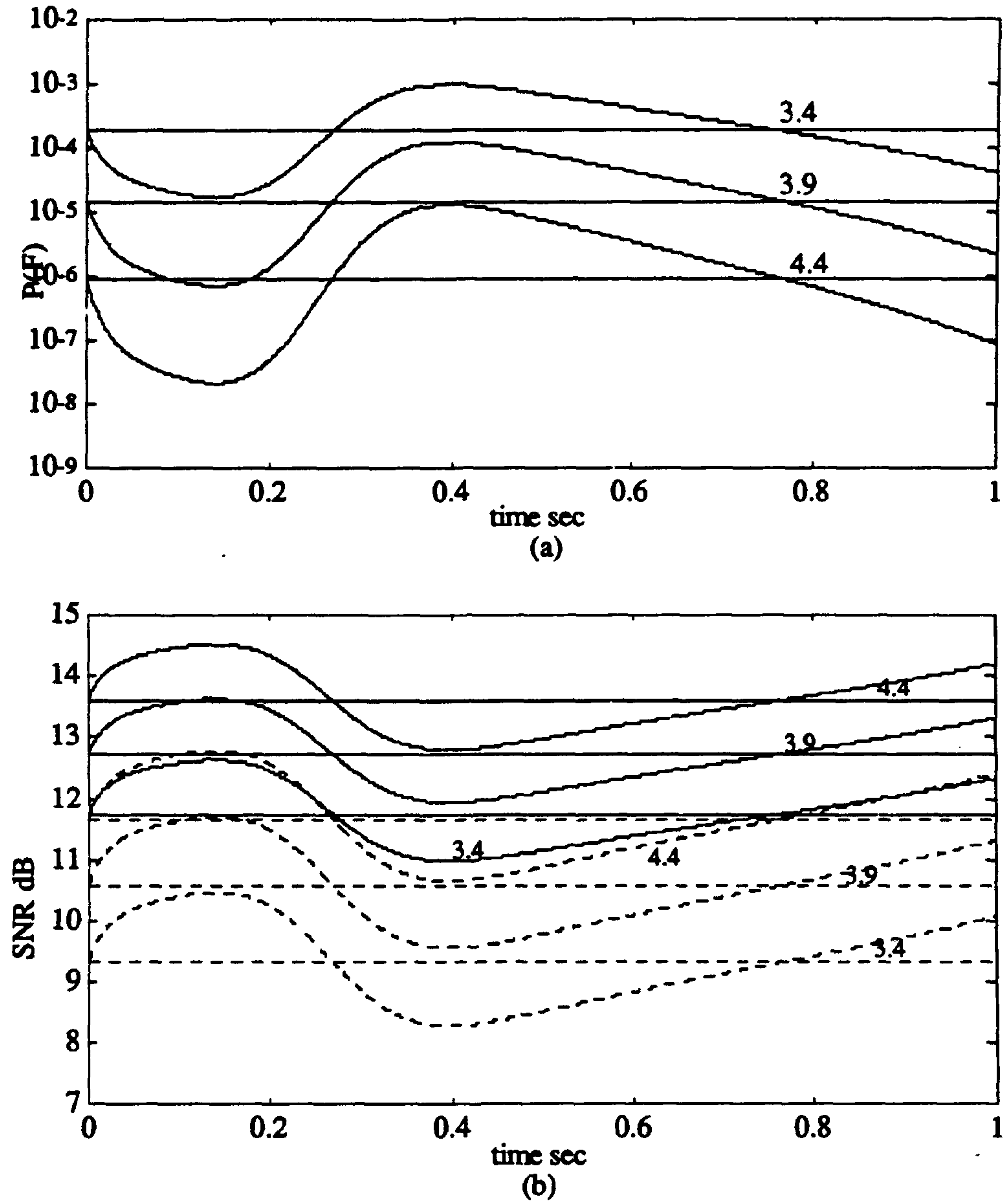


Figure (10) - Variation of P(F) and SNR for P(D) = 0.5 and 0.9 at $\lambda = \{3.4, 3.9, 4.4\}$ at the CW normalizer output for a sinusoidal noise amplitude variation is 15 dB over 1 sec. As the normalizer sweeps through the sinusoid P(F) decreases to $\{1.7479\times10^{-5},\ 7.2071\times10^{-7},\ 2.2135\times10^{-8}\}$ and then increases to $\{9.7705\times10^{-4}, 1.2543\times10^{-4}, 1.3074\times10^{-5}\}$; the SNR (at P(D) = 0.5, 0.9) increases to {10.46, 11.70, 12.78} and {12.63, 13.62, 14.51} and then decreases to {8.29, 9.56, 10.66} and {10.98, 11.94, 12.80} respectively. In stationary noise, P(F) = $\{1.8522\times10^{-4}, 1.4838\times10^{-5}, 9.3024\times10^{-7}\}$; SNR = {9.32, 10.57, 11.66} and {11.75, 12.72, 13.59}.

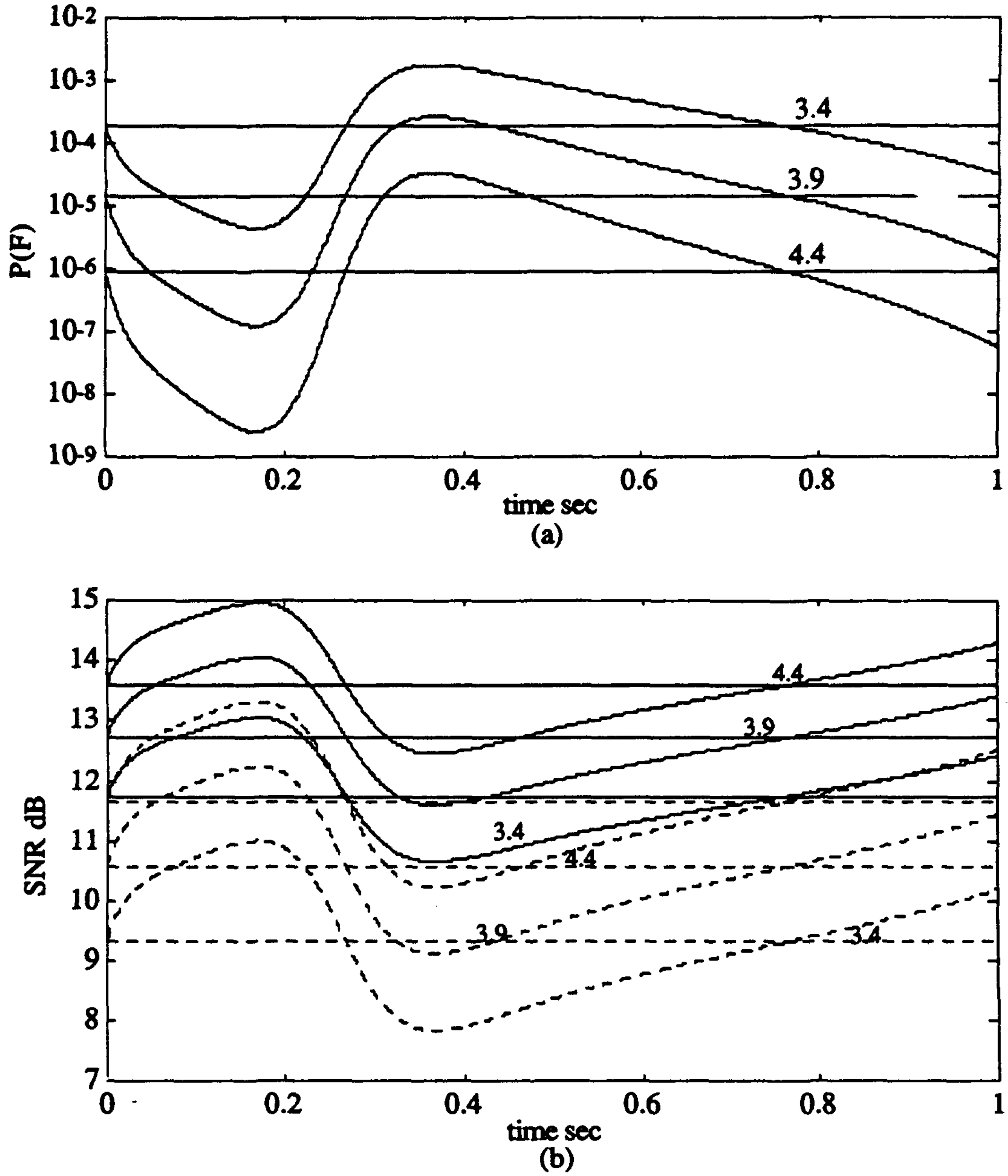


Figure (11) - Variation of P(F) and SNR for P(D) = 0.5 and 0.9 at $\lambda = \{3.4, 3.9, 4.4\}$ at the CW normalizer output for a sinusoidal noise amplitude variation is 20 dB over 1 sec. As the normalizer sweeps through the sinusoid P(F) decreases to $\{4.4954\times10^{-6}, 1.2692\times10^{-7}, 2.5993\times10^{-9}\}$ and then increases to $\{1.7950\times10^{-3}, 2.7407\times10^{-4}, 3.4459\times10^{-5}\}$; the SNR (at P(D) = 0.5, 0.9) increases to {11.01, 12.24, 13.32} and {13.06, 14.06, 14.96} and then decreases to {7.85, 9.13, 10.23} and {10.66, 11.61, 12.46} respectively. In stationary noise, P(F) = $\{1.8522\times10^{-4}, 1.4838\times10^{-5}, 9.3024\times10^{-7}\}$; SNR = {9.32, 10.57, 11.66} and {11.75, 12.72, 13.59}.

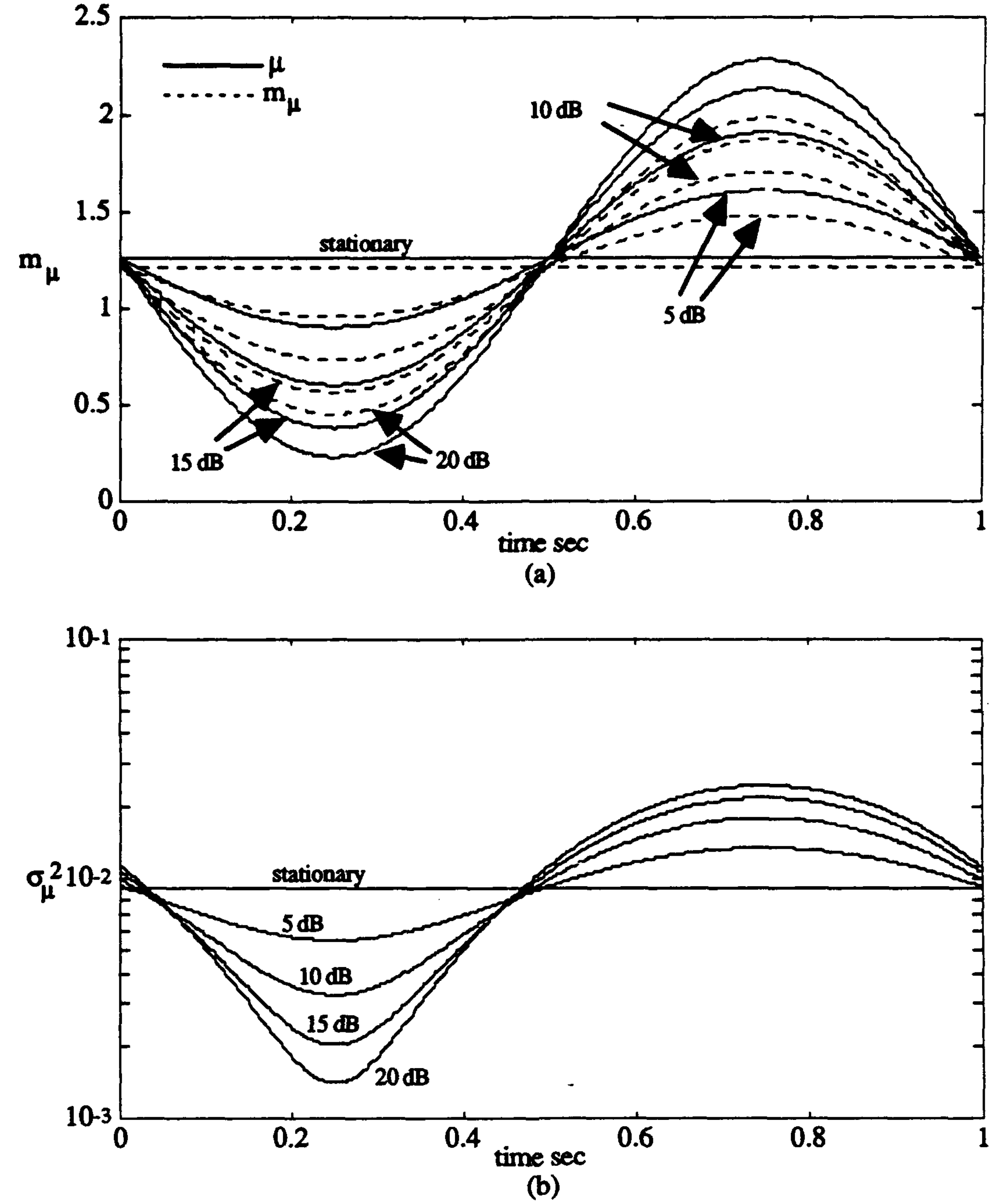
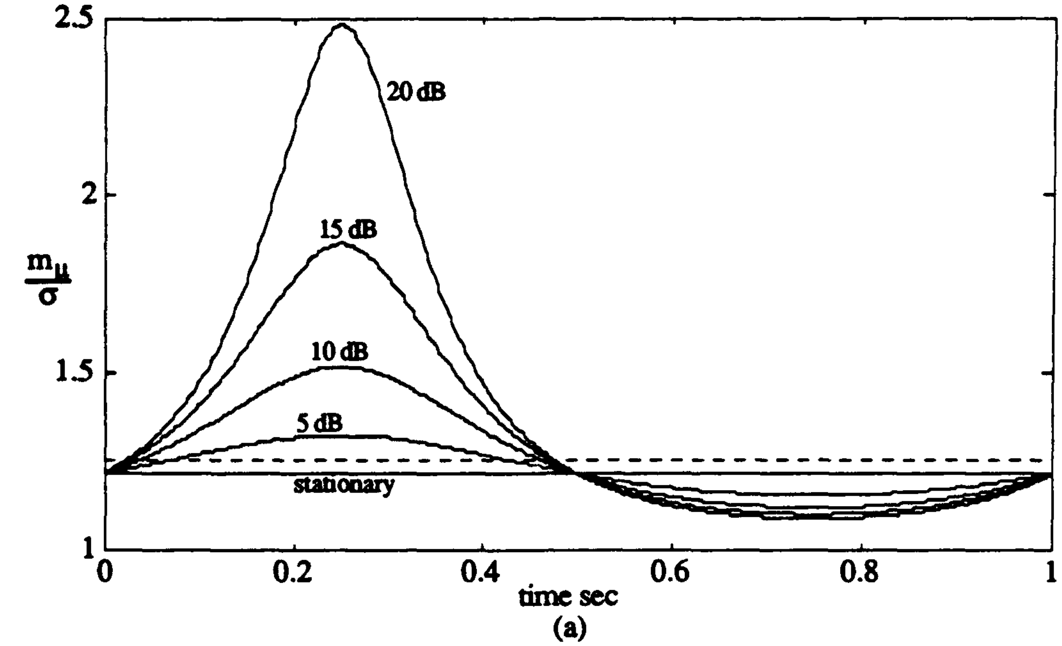


Figure (12) - Variation of the expected value of the FM normalizer mean estimate compared to the true mean and the variance of the mean esitmate for stationary noise and sinusoidal peak-to-peak noise amplitude variations of 5, 10, 15 and 20 dB. Under ideal conditions the mean estimate and variance equals $(\pi/2)^{1/2}$ and 0 respectively. For stationary noise the expected value and variance of the mean estimate are 1.215 and 8.9598×10^{-3} respectively. The difference between the true and estimated mean is the bias created by the normalizer which along with the variance of the estimate accounts for the degradation in normalizer performance.



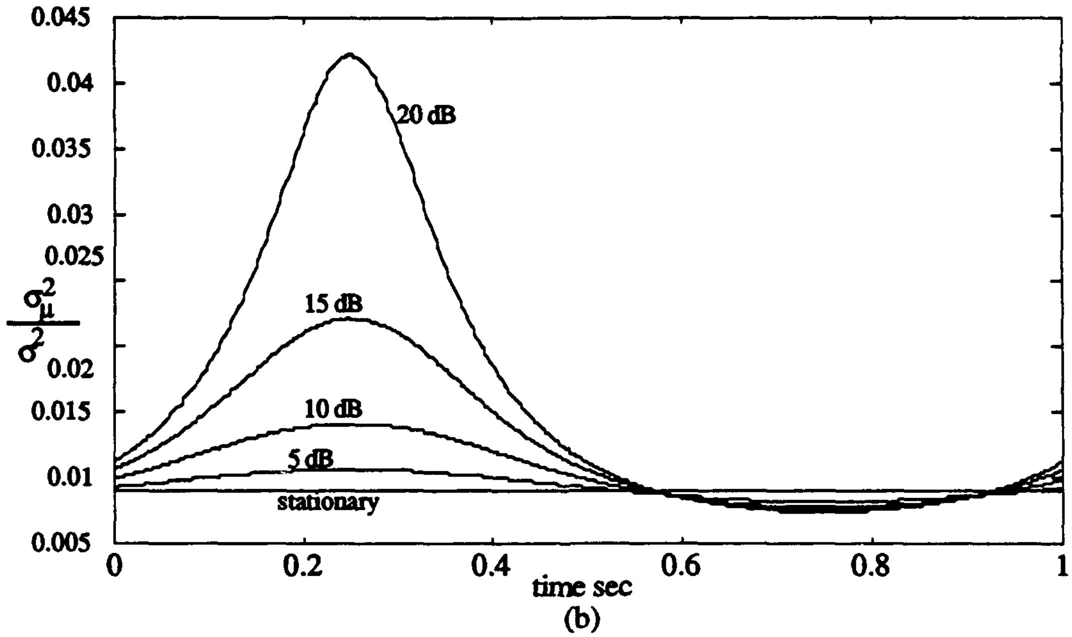


Figure (13) - Variation of the ratio of the expected value and variance of the estimated mean to true σ of the test cell being normalized for the 4 sinusoidal noise amplitudes at FM normalizer output. For an unbiased normalizer the ratio of the expected value of the mean estimate to σ is $(\pi/2)^{1/2}$. The bias in the mean estimation causes degredation in normalizer performance. The 48 effective independent samples in the estimate provides enough random error reduction of the mean estimate. The dashed line is the true mean value of each cell.

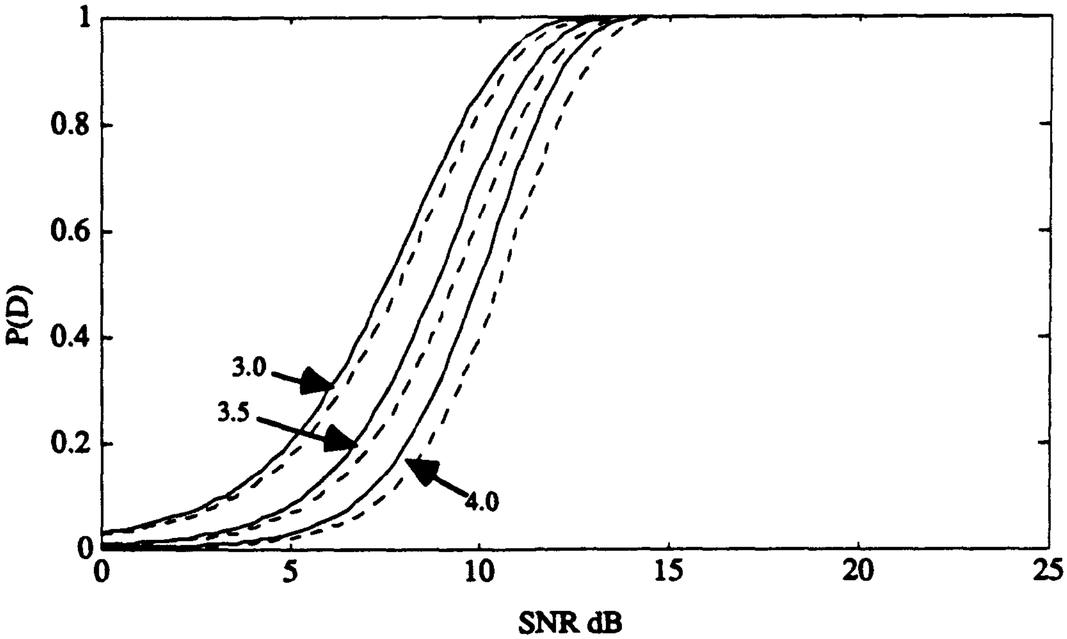


Figure (14) - Comparison of the theoretically ideal LFM ROC (solid) curves to the ROC curves in stationary (dashed) noise at thresholds $\lambda = \{3.0, 3.5, 4.0\}$. The theoretical ROC curve assumes the mean value of the noise is known exactly, i.e. it is a deterministic quantity. The ROC curves for the stationary noise are shifted to the left of the theoretical due to both the bias and the variance associated with the mean estimate. The P(F) associated to these curves are $\{1.85219\mathrm{x}10^{-04}, 1.48378\mathrm{x}10^{-05}, 9.30244\mathrm{x}10^{-07}\}$. The optimum performance of the LFM normalizer is given by the stationary noise ROC curves and are used in the figures following to compare performance under nonstationary noise conditions.

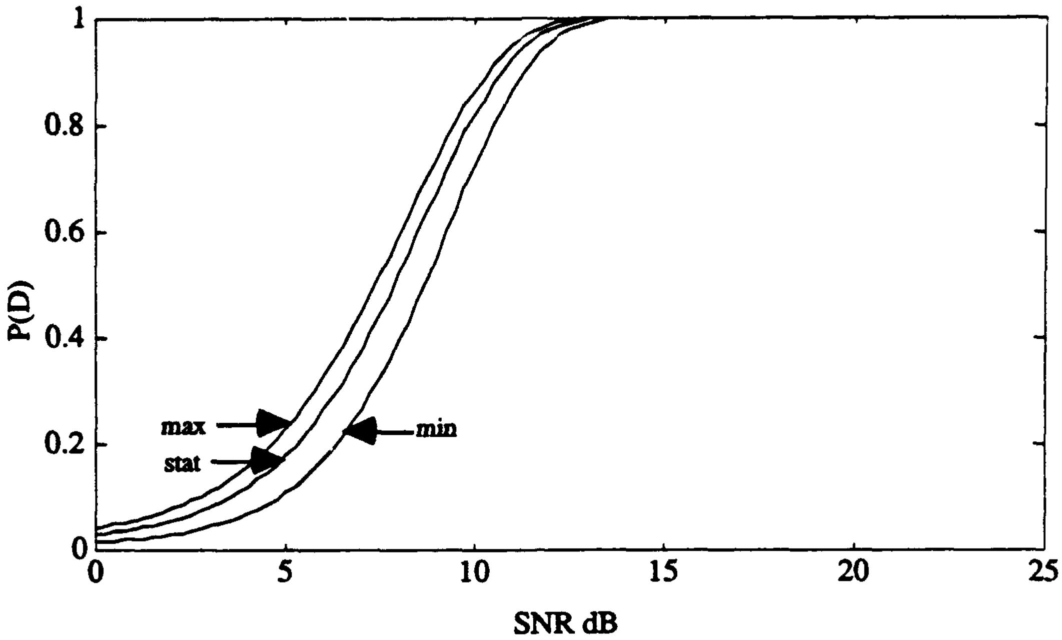


Figure (15a) - ROC curves at the output of the LFM normalizer. The curves depict performance under stationary and nonstationary noise with an amplitude variation of 5 dB peak-to-peak and 1 sec. period. The detection threshold is set to $\lambda = 3.0$. P(F) for stationary noise is 2.0587×10^{-3}; at the minimum and maximum P(F) are 7.0877×10^{-4} and 3.6510×10^{-3} respectively. For P(D) = 0.5 and 0.9 the required SNRs are (7.89, 10.73) for the stationary noise case and (8.69, 11.32) and (7.39, 10.36) at the minimum and maximum of the nonstationarity respectively.

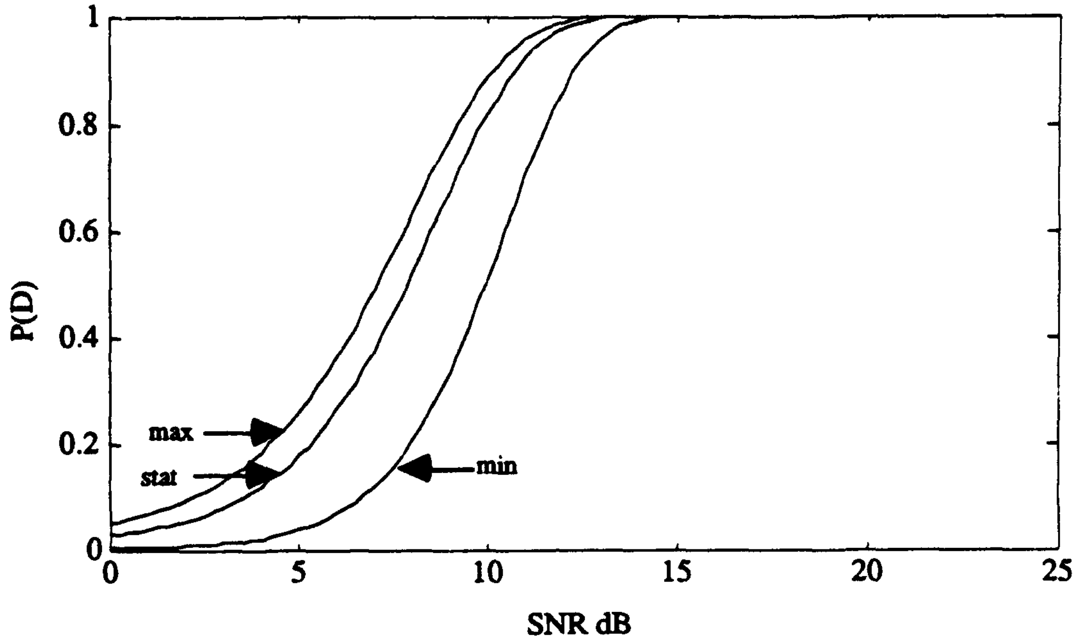


Figure (15b) - ROC curves at the output of the LFM normalizer. The curves depict performance under stationary and nonstationary noise with an amplitude variation of 10 dB peak-to-peak and 1 sec. period. The detection threshold is set to $\lambda = 3.0$. P(F) for stationary noise is 2.0587×10^{-3}; at the minimum and maximum P(F) are 9.3607×10^{-5} and 4.9924×10^{-3} respectively. For P(D) = 0.5 and 0.9 the required SNRs are (7.89, 10.73) for the stationary noise case and (9.95, 12.29) and (7.09, 10.16) at the minimum and maximum of the nonstationarity respectively.

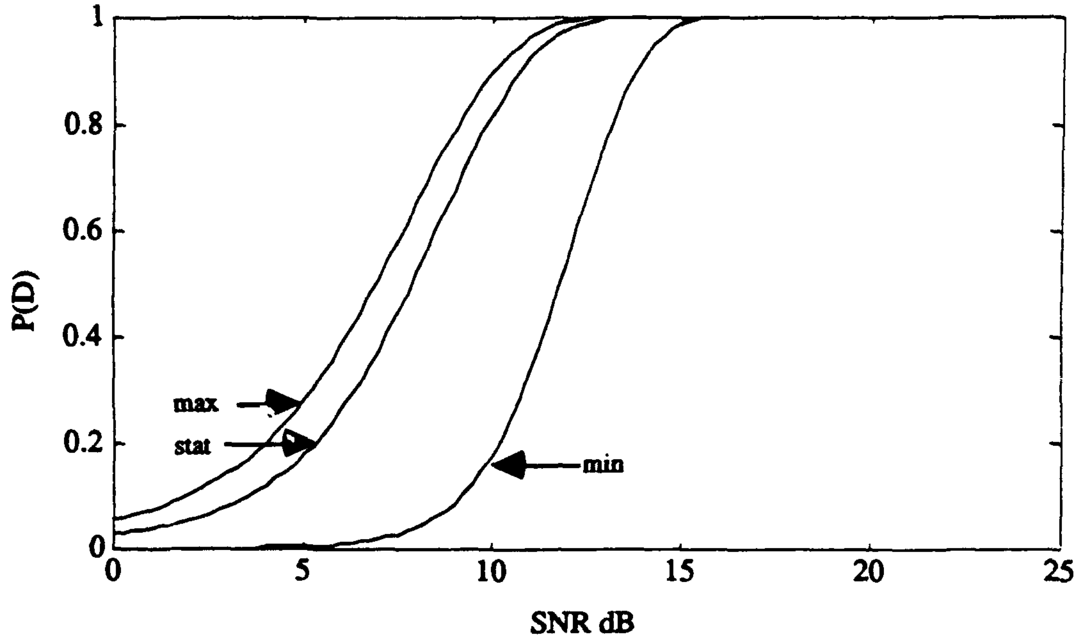


Figure (15c) - ROC curves at the output of the LFM normalizer. The curves depict performance under stationary and nonstationary noise with an amplitude variation of 15 dB peak-to-peak and 1 sec. period. The detection threshold is set to $\lambda = 3.0$. P(F) for stationary noise is 2.0587×10^{-3}; at the minimum and maximum P(F) are 1.9464×10^{-6} and 5.9348×10^{-3} respectively. For P(D) = 0.5 and 0.9 the required SNRs are (7.89, 10.73) for the stationary noise case and (11.80, 13.79) and (6.93, 10.04) at the minimum and maximum of the nonstationarity respectively.

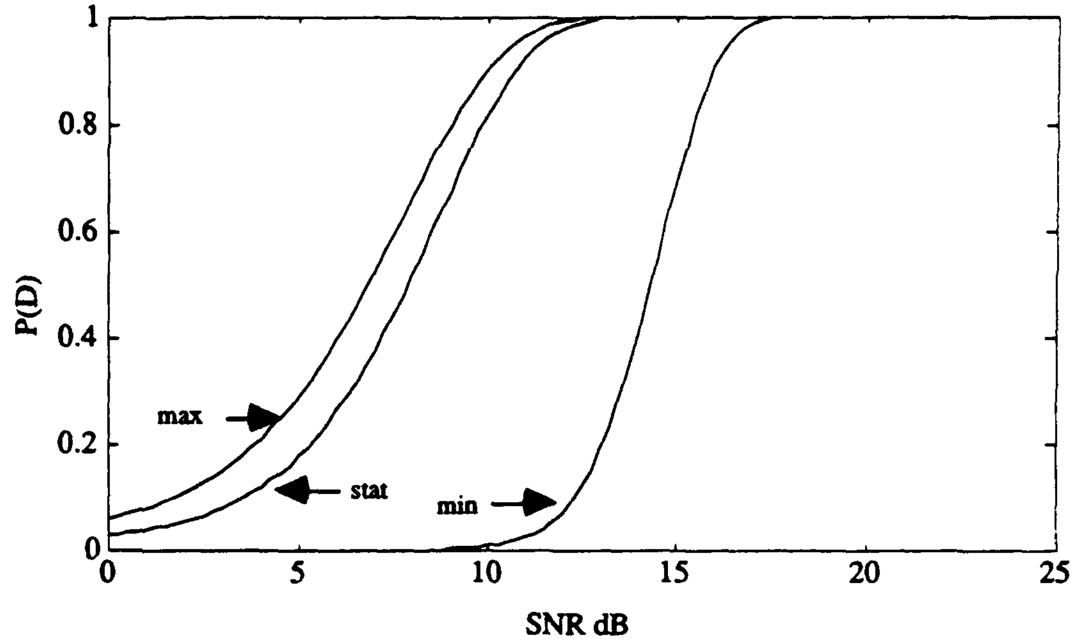


Figure (15d) - ROC curves at the output of the LFM normalizer. The curves depict performance under stationary and nonstationary noise with an amplitude variation of 20 dB peak-to-peak and 1 sec. period. The detection threshold is set to $\lambda = 3.0$. P(F) for stationary noise is 2.0587×10^{-3}; at the minimum and maximum P(F) are 1.6267×10^{-9} and 6.5345×10^{-3} respectively. For P(D) = 0.5 and 0.9 the required SNRs are (7.89, 10.73) for the stationary noise case and (14.43, 15.96) and (6.83, 9.97) at the minimum and maximum of the nonstationarity respectively.

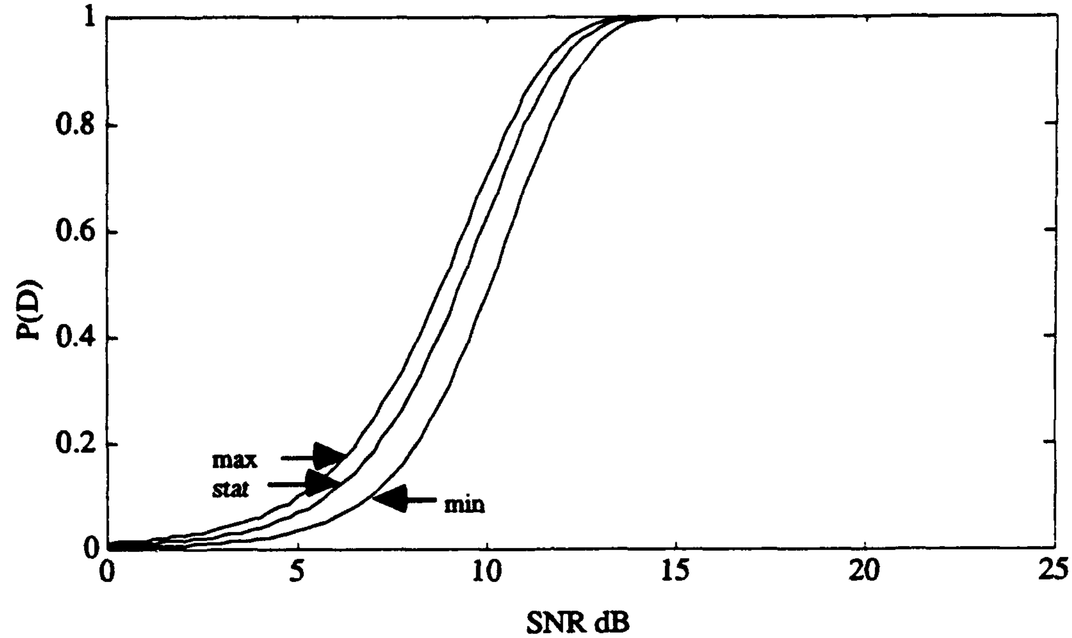


Figure (16a) - ROC curves at the output of the LFM normalizer. The curves depict performance under stationary and nonstationary noise with an amplitude variation of 5 dB peak-to-peak and 1 sec. period. The detection threshold is set to $\lambda = 3.5$. P(F) for stationary noise is 2.7488×10^{-4}; at the minimum and maximum P(F) are 6.9708×10^{-5} and 5.7778×10^{-4} respectively. For P(D) = 0.5 and 0.9 the required SNRs are (9.32, 11.81) for the stationary noise case and (10.10, 12.41) and (8.83, 11.43) at the minimum and maximum of the nonstationarity respectively.

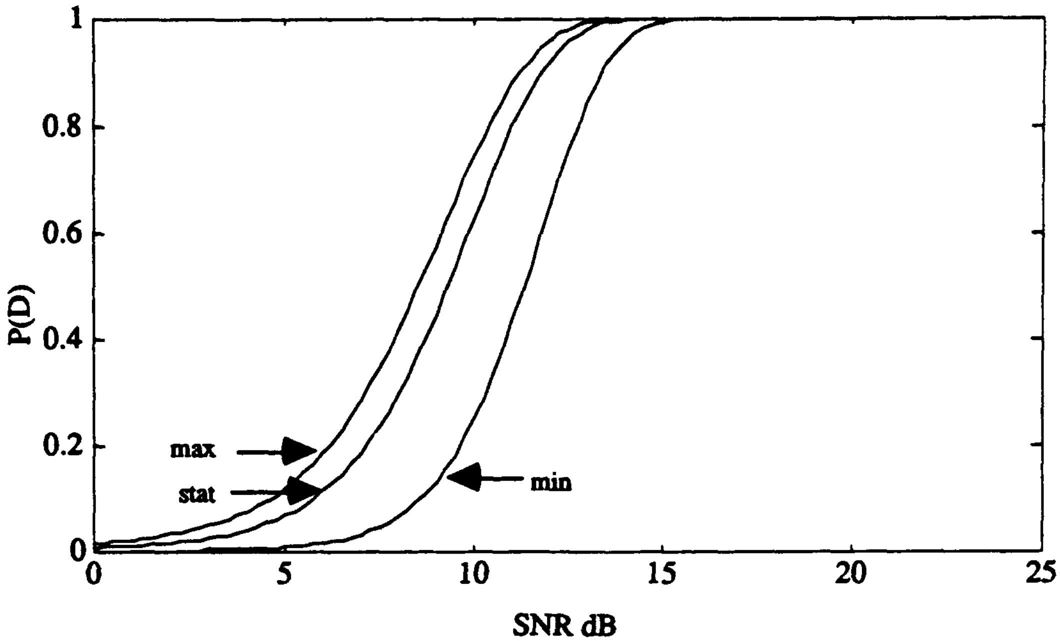


Figure (16b) - ROC curves at the output of the LFM normalizer. The curves depict performance under stationary and nonstationary noise with an amplitude variation of 10 dB peak-to-peak and 1 sec. period. The detection threshold is set to $\lambda = 3.5$. P(F) for stationary noise is 2.7488×10^{-4}; at the minimum and maximum P(F) are 5.3627×10^{-6} and 8.6839×10^{-4} respectively. For P(D) = 0.5 and 0.9 the required SNRs are (9.32, 11.81) for the stationary noise case and (11.34, 13.41) and (8.55, 11.22) at the minimum and maximum of the nonstationarity respectively.

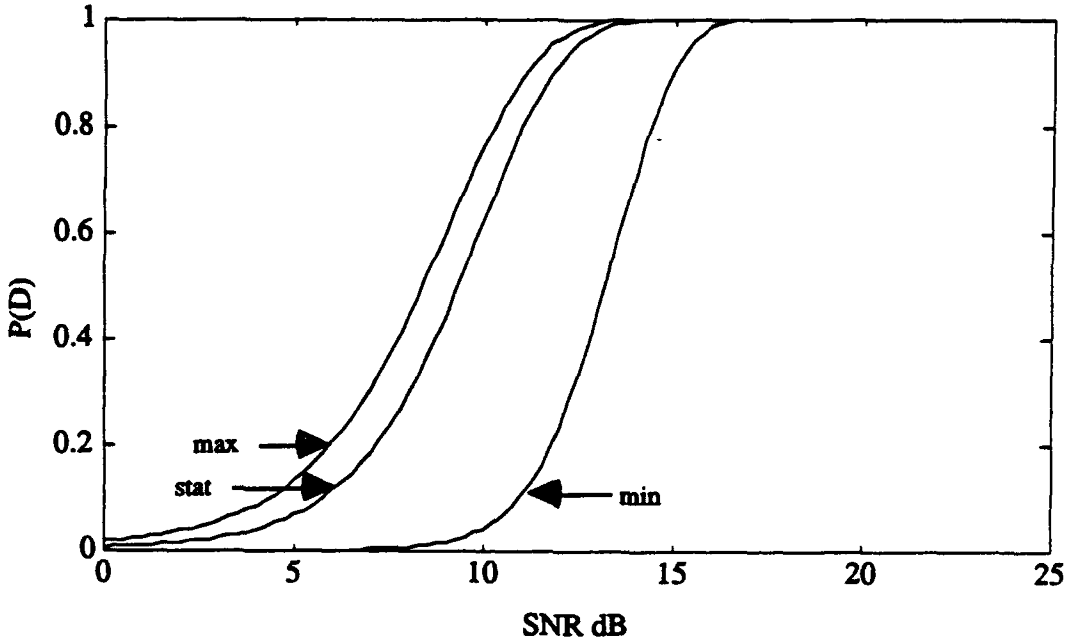


Figure (16c) - ROC curves at the output of the LFM normalizer. The curves depict performance under stationary and nonstationary noise with an amplitude variation of 15 dB peak-to-peak and 1 sec. period. The detection threshold is set to $\lambda = 3.5$. P(F) for stationary noise is 2.7488×10^{-4}; at the minimum and maximum P(F) are 4.6131×10^{-8} and 1.0882×10^{-3} respectively. For P(D) = 0.5 and 0.9 the required SNRs are (9.32, 11.81) for the stationary noise case and (13.18, 14.95) and (8.39, 11.09) at the minimum and maximum of the nonstationarity respectively.

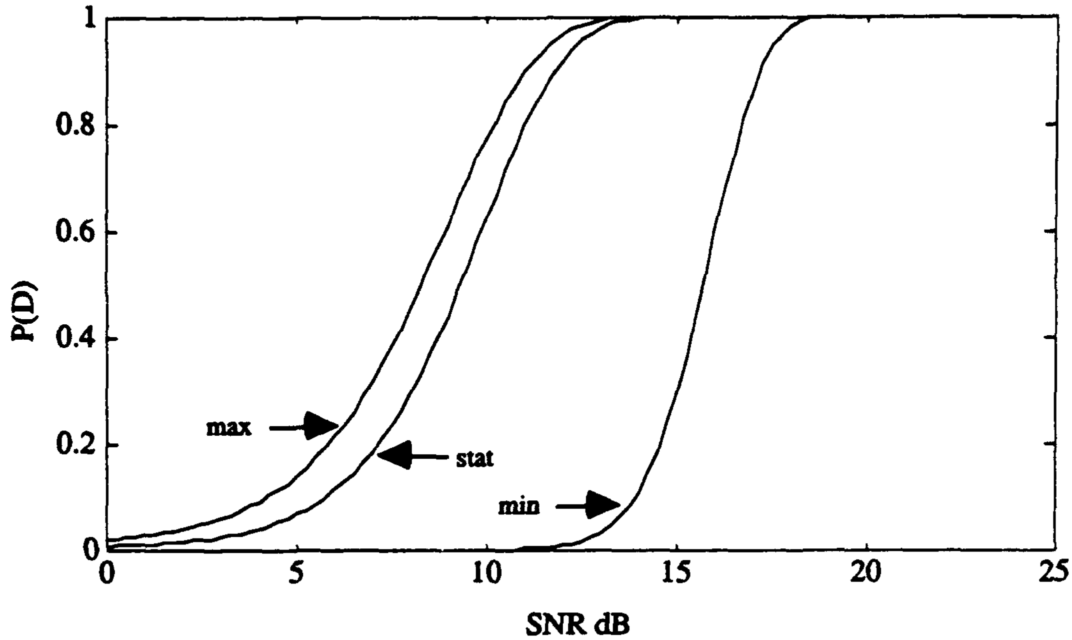


Figure (16d) - ROC curves at the output of the LFM normalizer. The curves depict performance under stationary and nonstationary noise with an amplitude variation of 20 dB peak-to-peak and 1 sec. period. The detection threshold is set to $\lambda = 3.5$. P(F) for stationary noise is 2.7488×10^{-4}; at the minimum and maximum P(F) are 1.2968×10^{-11} and 1.2340×10^{-3} respectively. For P(D) = 0.5 and 0.9 the required SNRs are (9.32, 11.81) for the stationary noise case and (15.70, 17.17) and (8.29, 11.02) at the minimum and maximum of the nonstationarity respectively.

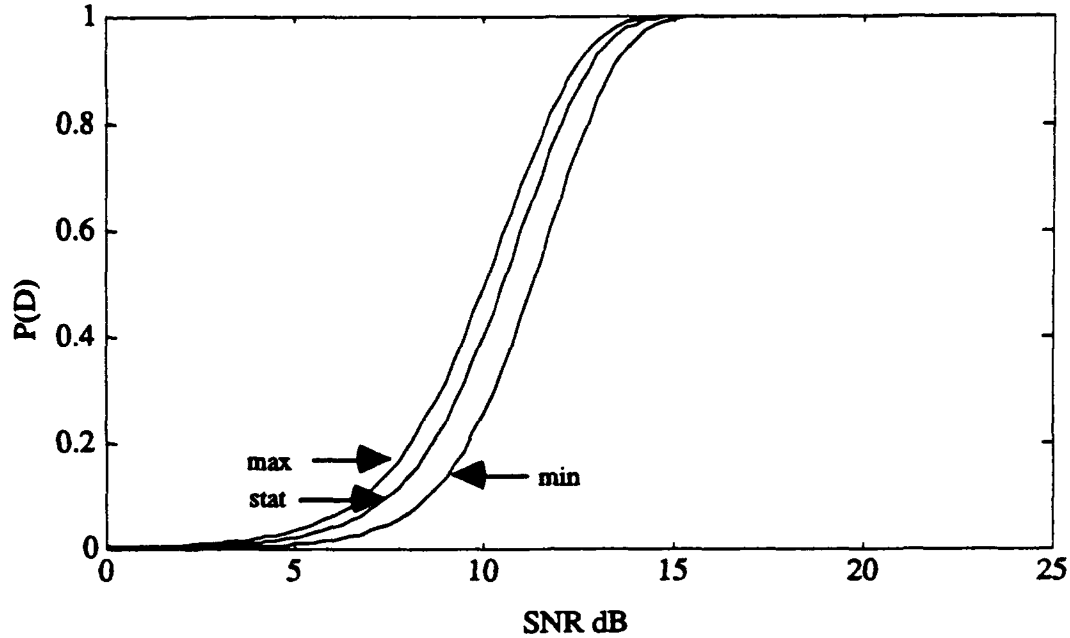


Figure (17a) - ROC curves at the output of the LFM normalizer. The curves depict performance under stationary and nonstationary noise with an amplitude variation of 5 dB peak-to-peak and 1 sec. period. The detection threshold is set to $\lambda = 4.0$. P(F) for stationary noise is 3.0573×10^{-5}; at the minimum and maximum P(F) are 5.6817×10^{-6} and 7.6629×10^{-5} respectively. For P(D) = 0.5 and 0.9 the required SNRs are (10.54, 12.76) for the stationary noise case and (11.31, 13.38) and (10.06, 12.38) at the minimum and maximum of the nonstationarity respectively.

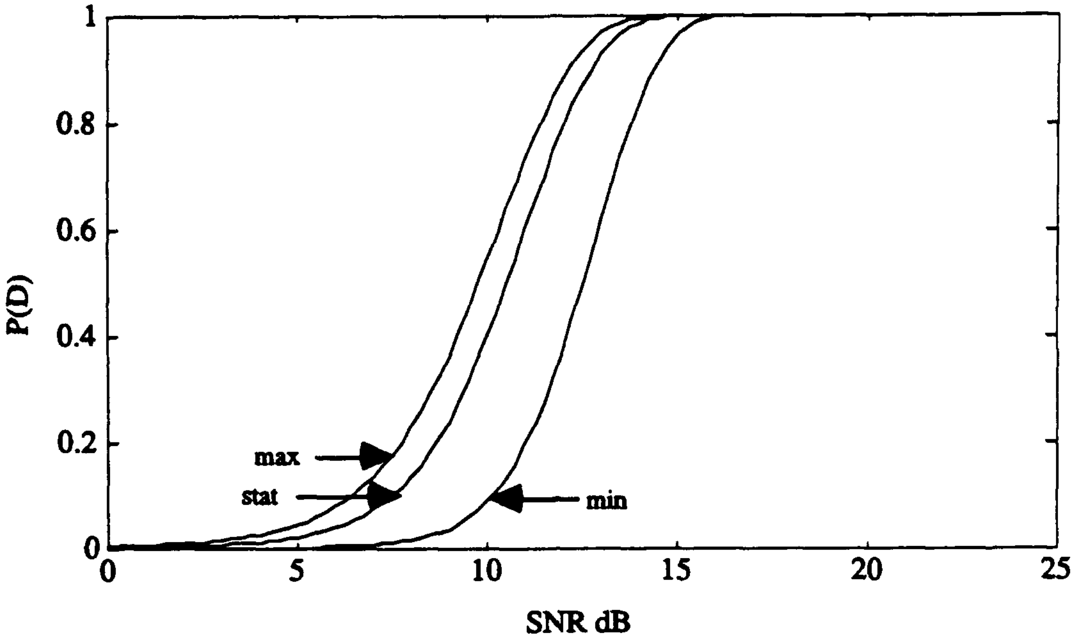


Figure (17b) - ROC curves at the output of the LFM normalizer. The curves depict performance under stationary and nonstationary noise with an amplitude variation of 10 dB peak-to-peak and 1 sec. period. The detection threshold is set to $\lambda = 4.0$. P(F) for stationary noise is 3.0573×10^{-5}; at the minimum and maximum P(F) are 2.5765×10^{-7} and 1.2714×10^{-4} respectively. For P(D) = 0.5 and 0.9 the required SNRs are (10.54, 12.76) for the stationary noise case and (12.54, 14.39) and (9.78, 12.16) at the minimum and maximum of the nonstationarity respectively.

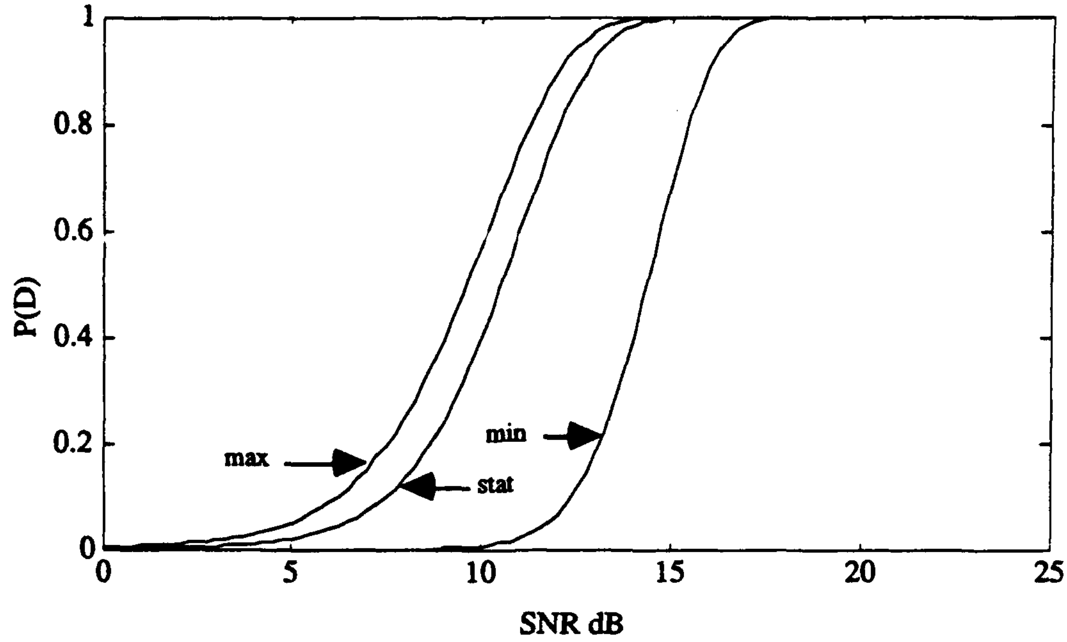


Figure (17c) - ROC curves at the output of the LFM normalizer. The curves depict performance under stationary and nonstationary noise with an amplitude variation of 15 dB peak-to-peak and 1 sec. period. The detection threshold is set to $\lambda = 4.0$. P(F) for stationary noise is 3.0573×10^{-5}; at the minimum and maximum P(F) are 1.0042×10^{-9} and 1.6840×10^{-4} respectively. For P(D) = 0.5 and 0.9 the required SNRs are (10.54, 12.76) for the stationary noise case and (14.37, 15.97) and (9.62, 12.04) at the minimum and maximum of the nonstationarity respectively.

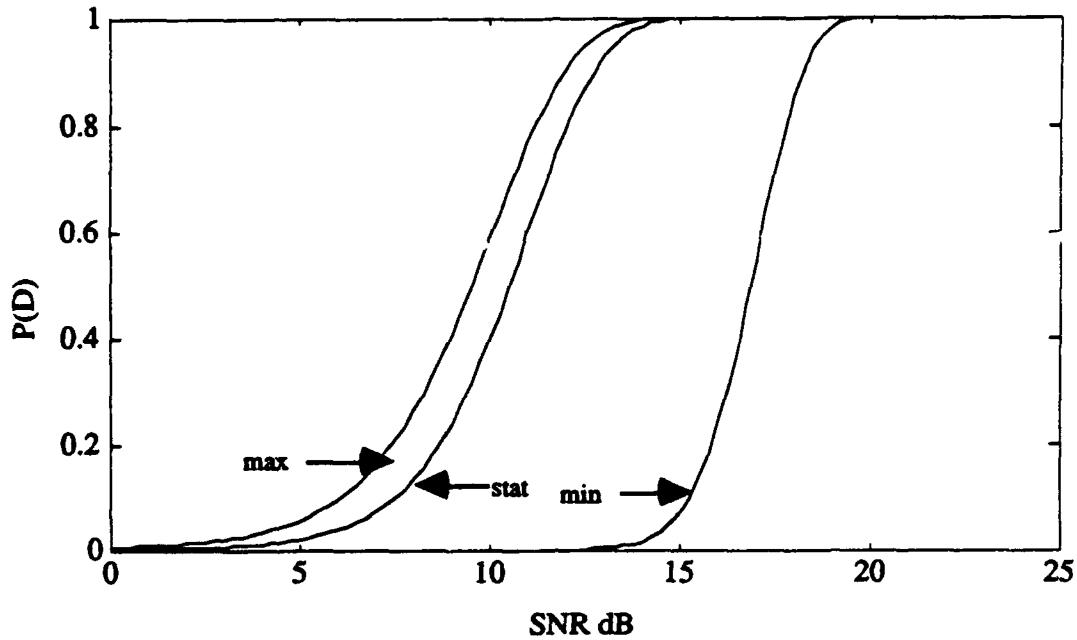


Figure (17d) - ROC curves at the output of the LFM normalizer. The curves depict performance under stationary and nonstationary noise with an amplitude variation of 20 dB peak-to-peak and 1 sec. period. The detection threshold is set to $\lambda = 4.0$. P(F) for stationary noise is 3.0573×10^{-5}; at the minimum and maximum P(F) are 1.3041×10^{-11} and 1.9700×10^{-4} respectively. For P(D) = 0.5 and 0.9 the required SNRs are (10.54, 12.76) for the stationary noise case and (16.88, 18.23) and (9.53, 11.97) at the minimum and maximum of the nonstationarity respectively.

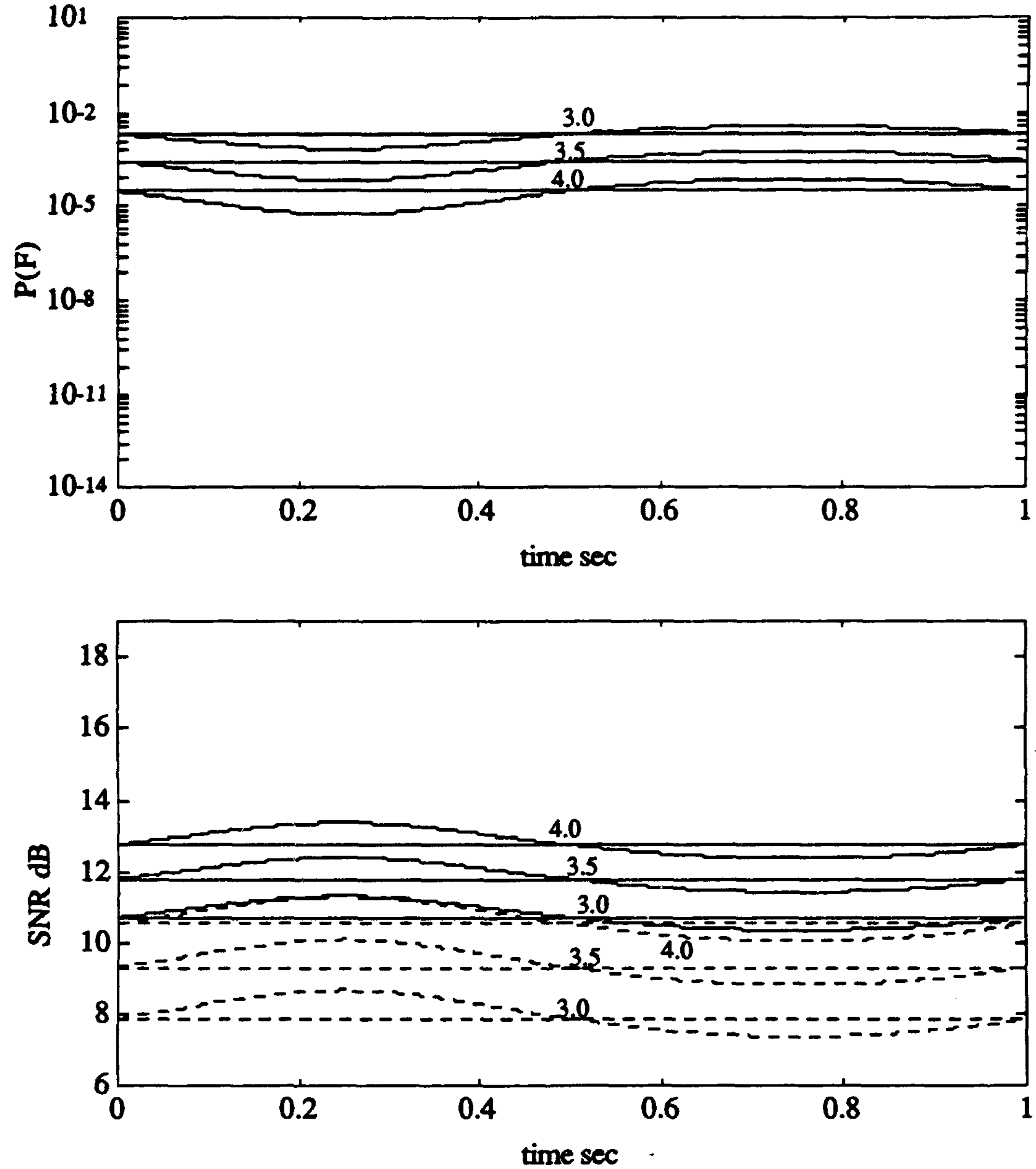


Figure (18) - Variation of P(F) and SNR for P(D) = 0.5 (dashed line) and 0.9 (solid line) at λ = {3.0, 3.5, 4.0} at the FM normalizer output for stationary and a sinusoidal noise amplitude variation of 5 dB over 1 sec. As the normalizer sweeps through the sinusoid P(F) decreases to {7.0877×10^{-4}, 6.9708×10^{-5}, 5.6817×10^{-6}} and then increases to {3.6510×10^{-3}, 5.7778×10^{-4}, 7.6629×10^{-6}}; the SNR (at P(D) = 0.5, 0.9) increases to {8.6841, 10.10, 11.31} and {11.32, 12.41, 13.80} and then decreases to {7.39, 8.84, 10.06} and {10.36, 11.43, 12.38} respectively. In stationary noise, P(F) = {2.0587×10^{-3}, 2.7488×10^{-4}, 3.0573×10^{-5}}; SNR = {7.89, 9.32, 10.54} and {10.73, 11.81, 12.76}.

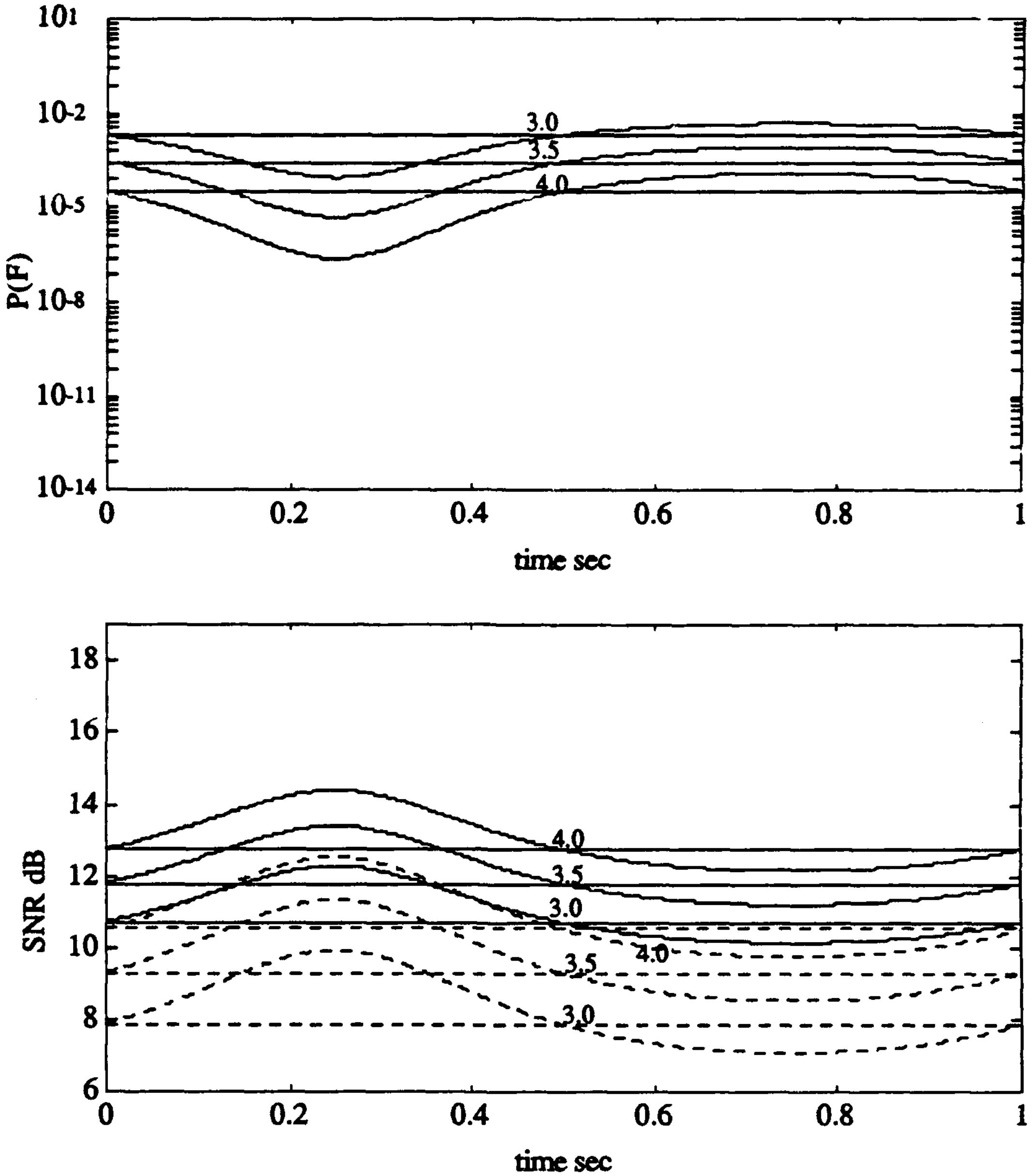


Figure (19) - Variation of P(F) and SNR for P(D) = 0.5 (dashed line) and 0.9 (solid line) at λ = {3.0, 3.5, 4.0} at the FM normalizer output for stationary and a sinusoidal noise amplitude variation of 10 dB over 1 sec. As the normalizer sweeps through the sinusoid P(F) decreases to {9.3607×10^{-5}, 5.3627×10^{-6}, 2.5765×10^{-7}} and then increases to {4.9924×10^{-3}, 8.6839×10^{-4}, 1.2714×10^{-4}}; the SNR (at P(D) = 0.5, 0.9) increases to {9.95, 11.34, 12.54} and {12.29, 13.41, 14.39} and then decreases to {7.01, 8.55, 9.78} and {10.16, 11.22, 12.16} respectively. In stationary noise, P(F) = {2.0587×10^{-3}, 2.7488×10^{-4}, 3.0573×10^{-5}}; SNR = {7.89, 9.32, 10.54} and {10.73, 11.81, 12.76}.

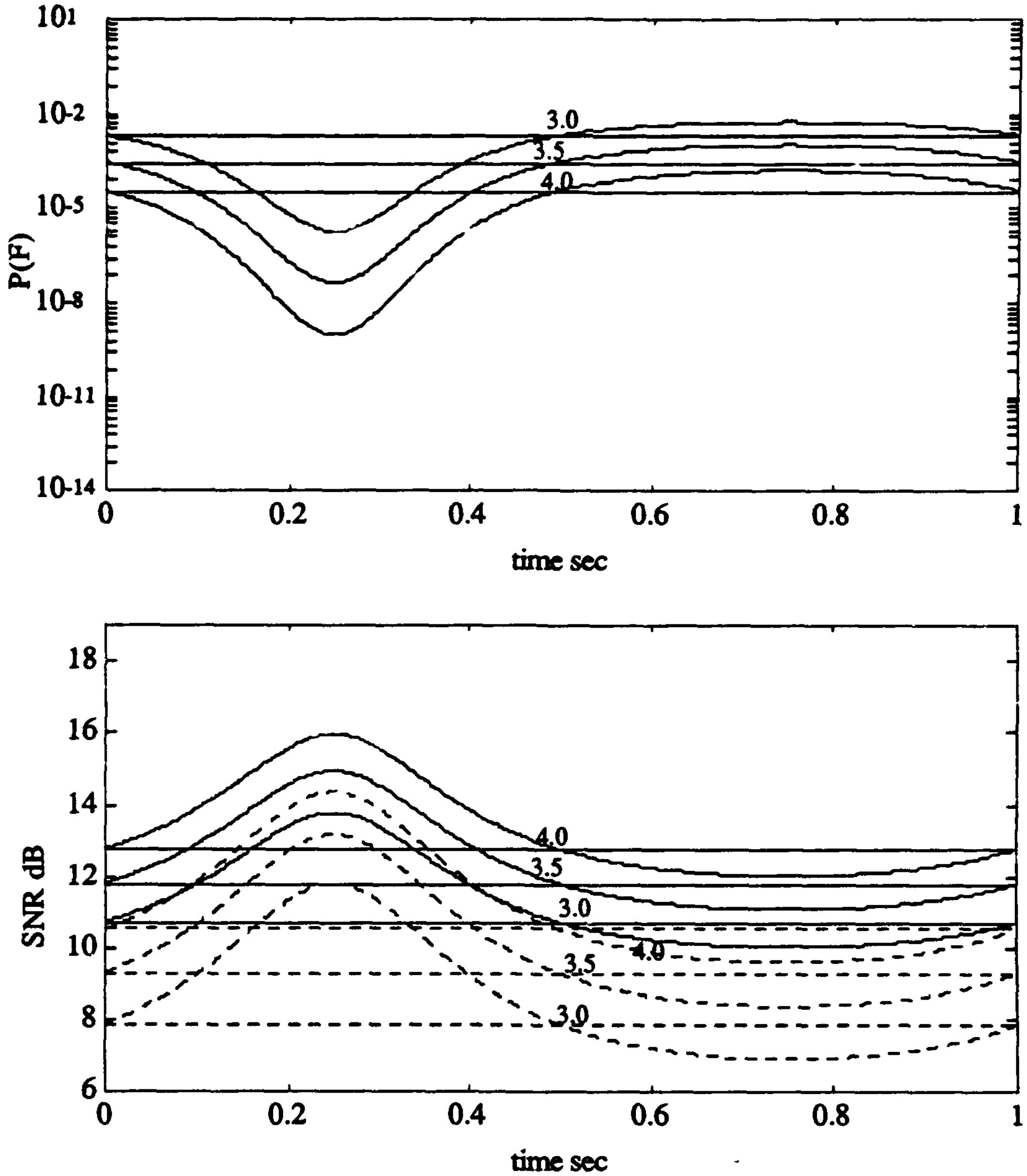


Figure (20) - Variation of P(F) and SNR for P(D) = 0.5 (dashed line) and 0.9 (solid line) at $\lambda = \{3.0, 3.5, 4.0\}$ at the FM normalizer output for stationary and a sinusoidal noise amplitude variation of 15 dB over 1 sec. As the normalizer sweeps through the sinusoid P(F) decreases to $\{1.9464\text{x}10^{-6},\ 4.6131\text{x}10^{-8},\ 1.0042\text{x}10^{-9}\}$ and then increases to $\{5.9348\text{x}10^{-3}, 1.0882\text{x}10^{-3}, 1.6840\text{x}10^{-4}\}$; the SNR (at P(D) = 0.5, 0.9) increases to {11.80, 13.18, 14.37} and {13.79, 14.95, 15.97} and then decreases to {6.93, 8.39, 9.62} and {10.04, 11.01, 12.04} respectively. In stationary noise, P(F) = $\{2.0587\text{x}10^{-3}, 2.7488\text{x}10^{-4}, 3.0573\text{x}10^{-5}\}$; SNR = {7.89, 9.32, 10.54} and {10.73, 11.81, 12.76}.

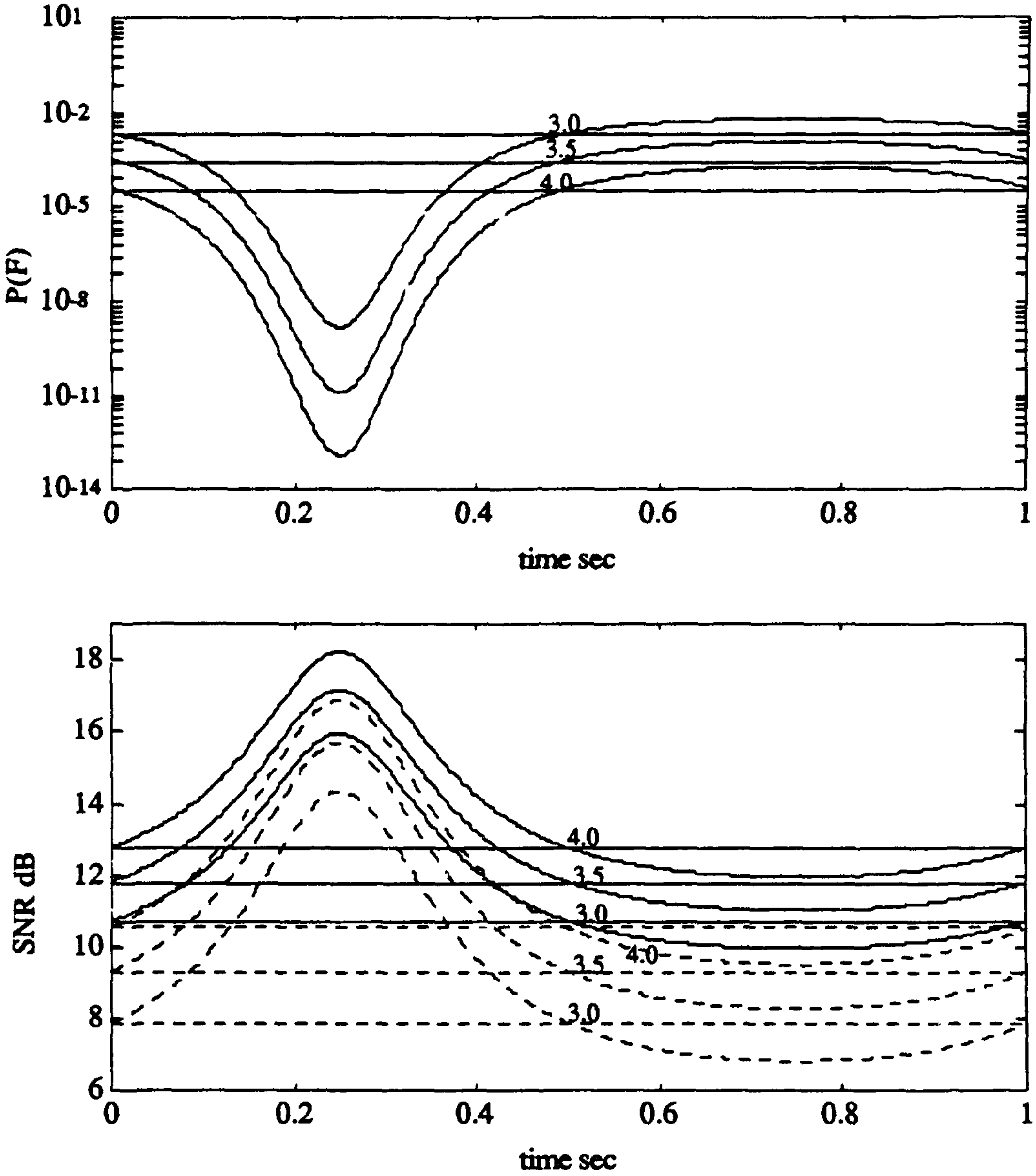


Figure (21) - Variation of P(F) and SNR for P(D) = 0.5 (dashed line) and 0.9 (solid line) at $\lambda = \{3.0, 3.5, 4.0\}$ at the FM normalizer output for stationary and a sinusoidal noise amplitude variation of 20 dB over 1 sec. As the normalizer sweeps through the sinusoid P(F) decreases to $\{1.6267\text{x}10^{-9},\ 1.2968\text{x}10^{-11},\ 1.3041\text{x}10^{-13}\}$ and then increases to $\{6.5345\text{x}10^{-3}, 1.2340\text{x}10^{-3}, 1.9700\text{x}10^{-4}\}$; the SNR (at P(D) = 0.5, 0.9) increases to {14.43, 15.70, 16.88} and {15.96, 17.12, 18.23} and then decreases to {6.83, 8.29, 9.53} and {9.98, 11.03, 11.97} respectively. In stationary noise, P(F) = $\{2.0587\text{x}10^{-3}, 2.7488\text{x}10^{-4}, 3.0573\text{x}10^{-5}\}$; SNR = {7.89, 9.32, 10.54} and {10.73, 11.81, 12.76}.

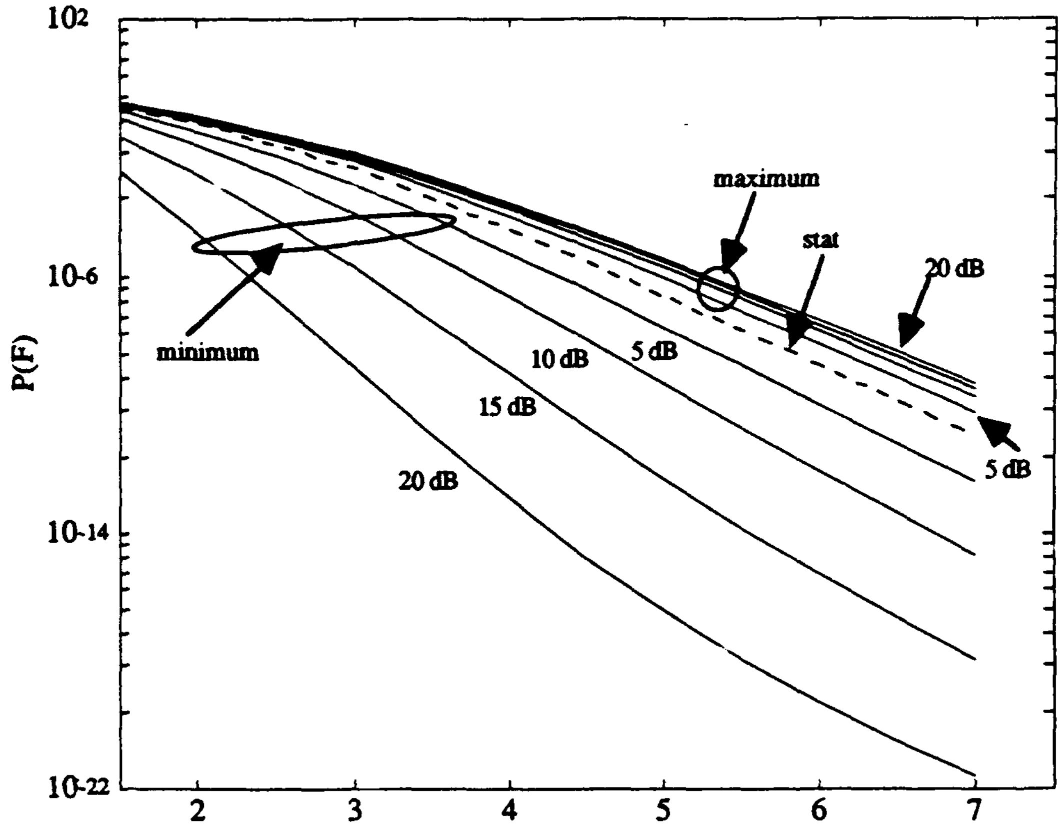


Figure (22) - Predicted change in P(F) for FM normalizer as a function of threshold in stationary noise and nonstationary noise. The change in nonstationary noise is plotted at the minimum and maximum of the sinusoidal changes of 5, 10, 15 and 20 dB. The plot shows the largest deviation about the stationary noise case which is the optimum case for the normalizer.

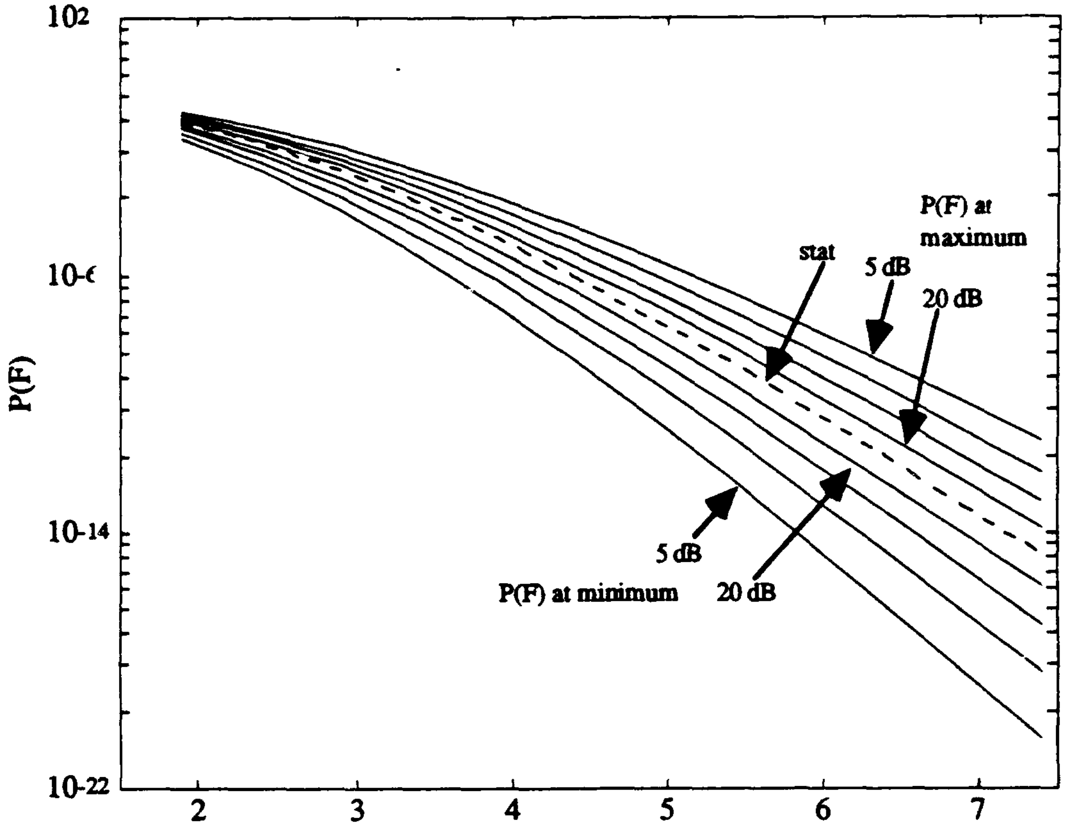


Figure (23) - Predicted change in P(F) for CW normalizer as a function of threshold in stationary noise and nonstationary noise. The change in nonstationary noise is plotted at the minimum and maximum of the sinusoidal changes of 5, 10, 15 and 20 dB. The plot shows the largest deviation about the stationary noise case which is the optimum case for the normalizer.

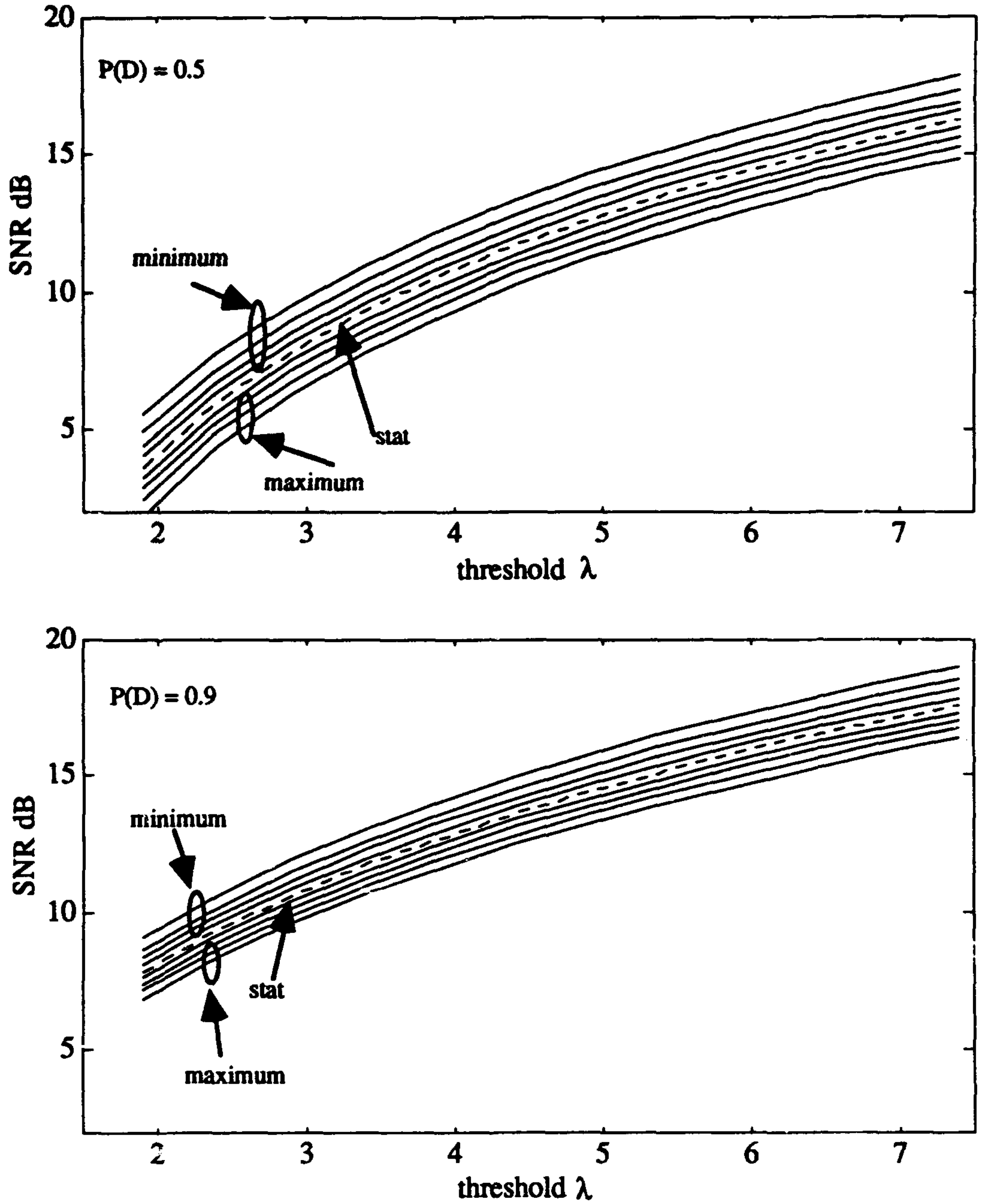
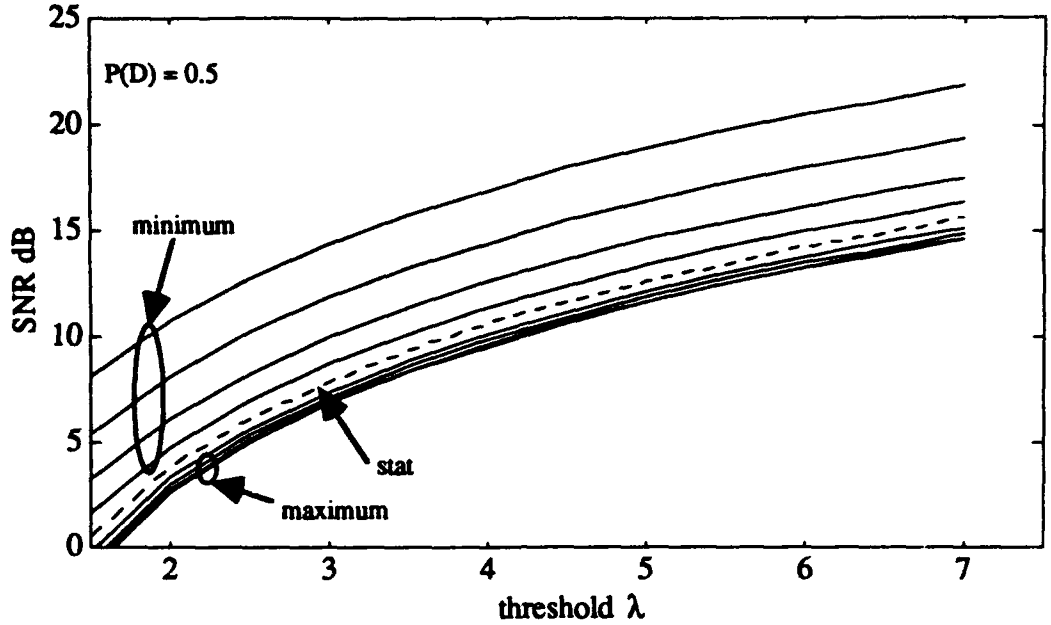


Figure (24) - Variation of the required SNR for P(D) = 0.5 and 0.9 at the CW normalizer output for stationary (dashed line) and nonstationary (solid line) noise. The SNRs in nonstationary noise are the values at the minimum and maximum of the 5, 10, 15 and 20 dB peak-to-peak sinusoidal amplitude variations. The plots show the largest deviation from the optimum SNRs (in stationary noise) for the 4 sinusoidal variations.



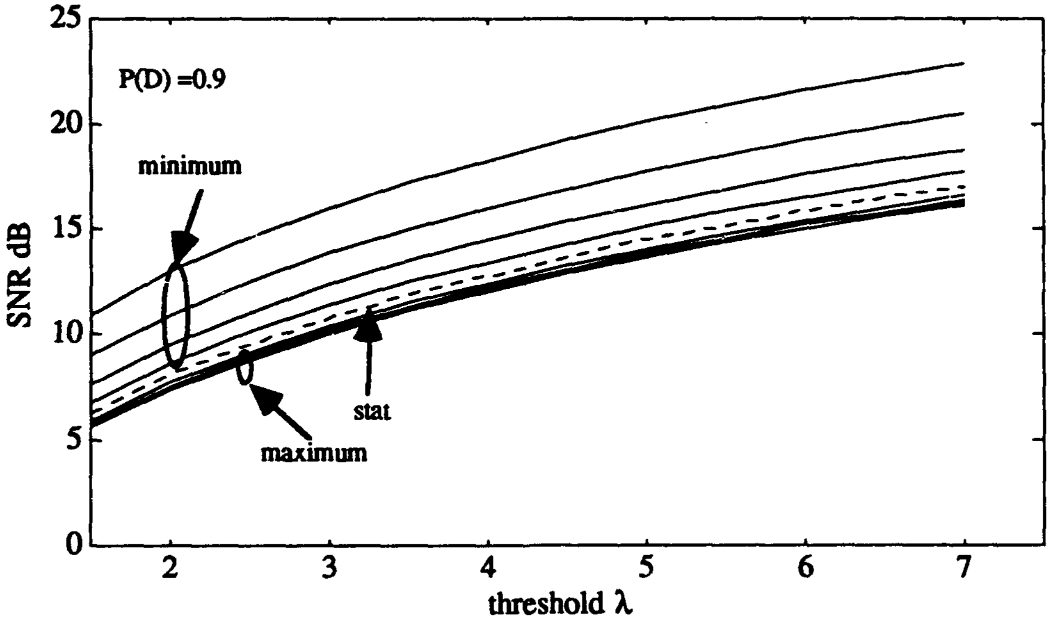


Figure (25) - Variation of the required SNR for P(D) = 0.5 and 0.9 at the FM normalizer output for stationary (dashed line) and nonstationary (solid line) noise. The SNRs in nonstationary noise are the values at the minimum and maximum of the 5, 10, 15 and 20 dB peak-to-peak sinusoidal amplitude variations. The plots show the largest deviation from the optimum SNRs (in stationary noise) for the 4 sinusoidal variations.

References

1. Khan, F. and Wenk, C.J. -"An Analytic performance Evaluation Design of the MFACP CW Normalizer," Naval Undersea Warfare Center, Tech Memo. 921205, 9 Sept 92.

2. Wenk, C.J. - "An Analytical Design and Evaluation Methodology for Active SONAR Normalizers (PRELIMINARY), "Analysis and Technology, Engineering Technology Center, Report no. P-4578-5-92, 15 March 92.